Single-Access Subdivisions Assessment Project:

Developing a Planning Tool for Evaluating Proposed Developments Accessible by Dead-End Roads

Prepared for

CAL FIRE and the California Board of Forestry and Fire Protection

By

California Polytechnic State University, San Luis Obispo

W. David Conn, Principal Investigator
Cornelius K. Nuworsoo, Co-Principal Investigator
Christopher A. Dicus, Co-Principal Investigator
Kenneth C. Topping, Senior Advisor
Dan Turner, Senior Consultant

CAL POLY
SAN LUIS OBISPO

June 2016

ACKNOWLEDGMENTS

The Cal Poly team thanks Jana Luis, who served initially as the Project Officer for CAL FIRE and continued to provide valued input after a promotion caused her to relinquish this formal role. Thanks are also due to CAL FIRE officials Pete Munoa, who took over as Project Officer, and Matt Damon. Edith Hannigan is thanked for her comments and suggestions as a consultant to the Board of Forestry and Fire Protection. The team is grateful to members of the Board for feedback following a March 2016 presentation of the draft final report in Sacramento, and to Board Member Marc Los Huertos in particular who visited the Cal Poly campus for further discussion.

Assistance in our efforts to model fire behavior was kindly provided by David Sapsis, David Passovoy, and Tadashi Moody, all of CAL FIRE's Fire and Resource Assessment Program.

The Cal Poly team also wishes to acknowledge contributions over the course of this project from several graduate student assistants and a few undergraduate students, all in City & Regional Planning at Cal Poly. The assistants were Lance Knox, Ben Rady, Ricky Williams, Jana Schwartz, Evelyn Garcia, Jose Palma, and Kip Morais. Additional assistance was provided by Kissila Santos, Julia Marques, and Felipe Schuckar, all undergraduate interns from Brazil.

Meg Henry kindly provided assistance as Project Research Analyst early in the project and subsequently helped to edit and format the final report. Natalie Macris is thanked for copy editing a draft of the final report.

This page intentionally left blank

Report Organization

This report is organized as follows.

Section 1.0, which is separable from the remainder of the document, provides an introduction to the issues posed by proposed developments accessible by dead-end roads; the applicable state regulations currently in existence and possible shortcomings thereof; the purpose of the study; the development of a planning tool; and some of the recommendations made by the study team. The rest of Section 1.0 comprises a user guide to the recommended six step procedure for applying the planning tool to the assessment of proposed (or existing) subdivisions.

Section 2.0 provides more information about the project, including details of the subdivision map approval process and the study's purpose and methodology. After describing how the access model is applied**, Section 3.0** reviews its use in an initial assessment of the existing regulatory standards based on hypothetical subdivision configurations. Application of the tool to fourteen case studies follows, producing a further assessment of the existing standards and preliminary conclusions about the relationship between subdivision design and the time needed for evacuation in the event of a wildfire. Fire behavior modeling is introduced in **Section 4.0**, leading to the development (with appropriate caveats) of a simplified set of look up tables for estimating rates of spread and flame lengths.

Section 5.0 contains illustrations of the manner in which information from fire behavior modeling might be used to assist planners in better understanding wildfire spread in various situations and relating this to estimates of clearance time.

The full set of recommendations developed by the Cal Poly study team is presented in **Section 6.0**.

Included in **Appendices 1 through 4** are: the results of a focused literature search; additional details on access modeling and fire behavior modeling; and a list the Cal Poly study team members.

This page intentionally left blank

TABLE OF CONTENTS

This page intentionally left blank

1.0 PLANNING TOOL USER GUIDE

Introduction

When a wildfire threatens a single-access subdivision, potentially life-threatening problems may arise when occupants seek to evacuate to a safe location while fire and other responders try to manage the emergency. Even when access is not disrupted by fire or smoke, factors such as inadequate road widths, steep grades, traffic congestion, and obstacles in the road can interfere with safe and timely egress and ingress, possibly causing entrapment of occupants and preventing responders from gaining access to do their job.

Under California's Subdivision Map Act (known as the "Map Act"), authority is given to cities and counties to regulate and control the subdivision of real property (see Figure 1-1 for example of typical subdivision map). Under the provisions of recent legislation[1], the agency having jurisdiction must find (among other things) that the design and location of a proposed subdivision within a state responsibility area (SRA) or locally-adopted very high fire hazard severity zone must be consistent with applicable regulations adopted by the State Board of Forestry and Fire Protection (the "Board") pursuant to Sections 4290 and 4291 of the Public Resources Code (PRC). Under PRC 4290, regulatory standards established in 1991 govern the maximum length of dead-end roads, including all additional dead-end roads accessed from the initial dead-end road**, regardless of the number of parcels served**
(see Table 1-1).[2]

Table 1-1: Dead-End Road Maximum Lengths (Current Standards)

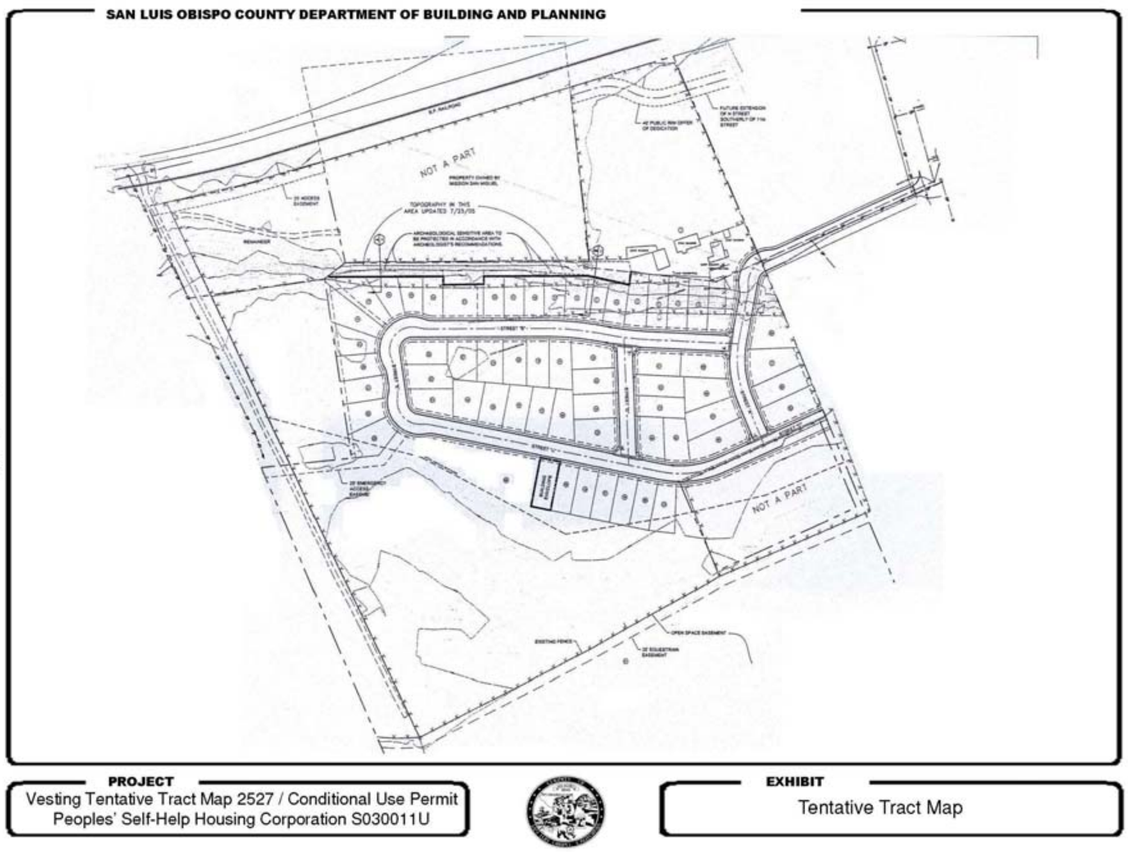
Parcel Size Allowed by Zoning	Maximum Dead-End Road Length
Less than 1 acre	800 feet
1 acre to 4.99 acres	1,320 feet
5 acres to 19.99 acres	2,640 feet
20 acres or larger	5,280 feet

The intent underlying the regulatory standards is to **"…provide for access for emergency wildland fire equipment and civilian evacuation concurrently, and…provide unobstructed traffic circulation during a wildfire emergency**."[3] Exceptions to the standards are permitted when it can be demonstrated that **"the same overall practical effect as the regulations"**[4] can be achieved, that is, if alternative practices effectively meet the regulatory intent of assuring safe egress and ingress of occupants and fire personnel/equipment.

---

[1] Senate Bill 1241 (2012), which amends Government Code Sections 65302 and 65302.5 and adds Sections 65040.20 and 66474.02 and adds Section 21083.01 to the Public Resources Code.
[2] Code of California Regulations, Title 14, Section 1273.09 Dead-End Roads.
[3] Code of California Regulations, Title 14, Section 1273.00 Intent.
[4] Code of California Regulations, Title 14, Section 1270.07 Exceptions to Standards.

Figure 1-1: Tentative Tract Map Example



Source: http://agenda.slocounty.ca.gov/agenda/sanluisobispo/5973/QXROY2ggMS5Qcm9qZWN0IEdyYXBoaWNzLnBkZg==/12/n/60920.doc

The maximum dead-end road lengths permitted by the standards depend **only** on parcel sizes allowed by zoning and do not take into account other factors affecting egress and ingress, such as:

- Land use (e.g., maximum allowable residential density under the general plan, square feet of commercial space, sizes of facilities such as schools, hospitals, etc. -- all determining the number of people potentially needing to exit the subdivision in the event of a fire)
- Demographics (e.g., proportions of youth, adults, seniors)
- Road system adequacy for proposed development (e.g., roadway width, grade, condition, connections to other roads, etc.)
- Fire hazard (e.g., presence and type of hazardous fuels, potential for extreme weather, adverse topography, etc.)
- The location of, and conditions at, the intersection where occupants exit from the dead-end road, which itself may not be safe in the event of a fire

Because they do not take into account these other factors, the current standards in many instances do not adequately provide for safe egress and ingress of occupants and fire personnel/equipment in the event of a fire. Furthermore, in situations where proposed dead-end roads would exceed the maximum lengths specified in the standard, the standards give no guidance on how to determine whether "the same practical effect" might be achieved by mitigation (e.g., by controlling the mix and intensity of residential and commercial land uses, adjusting the roadway characteristics, etc.).

It should be noted that the current standards make no explicit reference to the time needed for safe egress or ingress. However, implicit assumptions about time are built in to the standards. For example, by specifying a maximum dead-end road length of 800 feet in a single-access subdivision zoned for parcels below 1 acre in size, the **implicit** assumption is made that the occupants could be evacuated along a road of this length in less time than it would take for a fire to overtake them. The standards also make no reference to where a fire might start, nor to the conditions (e.g., vegetation, topography, wind speed, moisture level, etc.,) that affect fire behavior once ignition has occurred.

The present study was intended to assess the current standards, to provide a defensible foundation for establishing new standards if needed, and to develop a simple-to-use planning tool based on computer modeling that can be applied by jurisdictions, developers, and others to (1) judge whether a project proposal is likely to satisfy the "same practical effect" criterion, and (2) assist them in identifying mitigation options that will enable this criterion to be met.

For these purposes, the Cal Poly team sought to devise procedures to model how long it takes, in the event of a fire, for:

- Occupants of a single-access subdivision to reach an intersection with a through road, defined for purpose of the study as a road that gives a choice of two or more directions in which to travel from the intersection; and
- Fire personnel/equipment to reach where they need to be in order to fight the fire.

The team's modeling efforts led to the development of a planning tool that estimates how quickly occupants can leave a subdivision as a function of:

- Intensity of development or number of people to evacuate (expressed in number of vehicles);
- Physical size of development or distance to traverse;
- Potential travel speed for the given design speed of segments in the road network; and
- Design speed of roadway segments.

As it turned out, however, despite having response time data from around the state (as reported to CAL FIRE), it was not possible to model with adequate confidence the time taken for fire personnel/equipment to reach a fire (as opposed to occupants evacuating). Also, although the initial hope was to incorporate fire behavior as a variable directly into the access model and the resulting tool, without a fire behavior expert involved in each application of the tool, this did not prove possible. However, the team was able to develop a simplified fire behavior model allowing planners and others to consider evacuation time information (from applying the tool) in light of information about the likely rate of spread and intensity of a wildfire.

Based on findings from applying the models to both hypothetical and actual case study locations, the study led to several recommendations, including the following:[5]

1. **Replace Existing Table of Maximum Road Lengths.** The existing table of maximum road lengths specified in the Code of California Regulations, Title 14, Section 1273.09 Dead-End Roads regulation should be replaced, following sufficient beta testing, with the ***procedure for applying the planning tool*** described below, for the following reasons:

    a. Maximum dead-end road lengths are based solely on parcel size.
    b. The standards assume that subdivisions are only for single-family residential uses.
    c. The standards place no limit on the number of lots in subdivisions.
    d. The standards allow for stacking of multiple roadways within maximum length limits.
    e. The standards do not provide for reasonable evacuation times for all road length categories.
    f. The standards do not consider other land uses such as commercial uses, apartments, or schools.
    g. The standards do not take into account potential long-term land use intensification.
    h. There is no clearly stated enforcement mechanism or penalty for non-compliance.

2. **Seek Collaboration**. CAL FIRE and the Board of Forestry & Fire Protection should seek collaboration during beta testing with partner organizations such as the Governor's Office of Emergency Services (Cal OES), Governor's Office of Planning (OPR), League of California Cities, California State Association of Counties (CSAC), Rural County Representatives of California (RCRC), California Fire Chiefs Association (CalChiefs), and National Fire Protection Association (NFPA). Beta testing should be supported by training workshops organized by CAL FIRE. Collaborative attention should be given during beta testing to identification of sustainable funding mechanisms offsetting and financing hazard mitigation costs, such as Mello-Roos Community Facilities Districts.

3. **New Regulation**. When finalized, the recommended planning tool procedure should ***fully replace*** the current dead-end street length regulation through ***state adoption of a new regulation requiring application of the procedure*** by local agencies in:

    a. ***Single-access*** subdivisions proposed in an SRA area categorized as either a ***Moderate*** or ***High*** Fire Hazard Severity Zone (FHSZ),
    b. ***All*** subdivisions proposed in an SRA area categorized as a ***Very High*** FHSZ, and
    c. ***All*** single-access subdivisions in a state recommended and locally adopted ***Very High*** FHSZ within an LRA.

[5] The full set of recommendations is presented in section 6.0 of the report.

Purpose of the User Guide

The purpose of this guide is to explain how the planning tool developed by this study can be used to assess whether a proposed or existing single-access subdivision, with or without use of hazard mitigation measures, can meet the intent of California regulations implementing Section 4290 of the California Public Resources Code (PRC) to assure safe egress and ingress of occupants and fire personnel/equipment.

Intended Users

Intended users of the guide include developers, consultants, planners, engineers, fire protection and emergency response professionals, local governing bodies, and others charged with reviewing and/or approving development proposals under the Subdivision Map Act.

Nature of Tool

The tool is intended to be user-friendly. It is based on:

- Access modeling that estimates how quickly occupants can leave a subdivision as a function of:
  - Intensity of development or number of people to evacuate (expressed in number of vehicles);
  - Physical size of development or distance to traverse;
  - Potential travel speed for the given design speed of segments in the road network; and
  - Design speed of roadway segments.
- Fire behavior modeling under the conditions of a "normally severe fire weather day," providing (in look-up tables) rates of spread and flame lengths based on wind speed, with vegetation specified in one of four general categories.

Hosting of Tool

Online hosting of the tool by CAL FIRE is proposed, with maintenance and updates by Cal Poly.

Procedure for Applying the Planning Tool

The remainder of Section 1.0 gives a description of the recommended procedure for applying the Planning Tool. The recommended procedure focuses on maximizing the likelihood that a subdivision developer has control over, and can be required to implement, mitigation measures that will protect occupants attempting to evacuate in the event of a wildfire (or other hazard). The procedure combines estimates of the total time needed to evacuate a proposed subdivision and the fire spread rate without mitigation in order to calculate how near to evacuation routes a fire can be before its movement threatens to overtake occupants before they can clear the subdivision. It then considers whether vegetation management would shorten this distance, as necessary, in order to avoid the need for mitigation outside the subdivision's boundaries, over which the developer almost certainly lacks control. Depending on the circumstances, the procedure may point to the need for further mitigation measures, such as changes to the access layout (e.g., additional exits, more roadway lanes, etc.), size and numbers of lots, land uses, and/or development density.

The steps in the procedure are outlined in Figure 1-2 below and explained in the narrative. It should be noted that this Planning Tool is useful for mitigating wildfire hazards in ***existing*** as well as proposed subdivisions, as will be seen in the following discussion.

NOTE: The planning procedure presented here is based on a fire that is a "NO NOTICE EVENT," meaning that incident managers do not have adequate time to plan or coordinate an evacuation though advance warnings. Occupants typically will receive notice to evacuate via Reverse 9-1-1 ©, other warning systems, or personal observation. There may or may not be response personnel present to assist in evacuation.

The procedure requires use of the following input data common to land use planning and environmental analysis under the California Environmental Quality Act (CEQA) procedures:

- Tentative subdivision map
- Road network map of subject property and vicinity, including through road connections to other road networks
- Existing land ownership parcel map of subject property and vicinity
- Land use map of subject property and vicinity
- Existing zoning map of subject property and vicinity
- Map of general plan designations for ultimate land uses of subject property and vicinity
- Vegetation map of subject property and vicinity
- Wind speed
- Topographic map and average slope of subject property and vicinity

Figure 1-2: Single-Access Tentative Subdivision Map Review Procedure

STEP 1:

Calculate Evacuation Time

↓

STEP 2:

Estimate Fire Spread Rate

↓

STEP 3:

Determine Fire Risk Mitigation Envelope (defined in narrative)

↓

STEP 4:

Determine if Fuel Management would Reduce the Fire Risk Mitigation Envelope to within Subdivision

↓

STEP 5:

Select Fire Risk Mitigation Measures and Subdivision Design Modifications

↓

STEP 6:

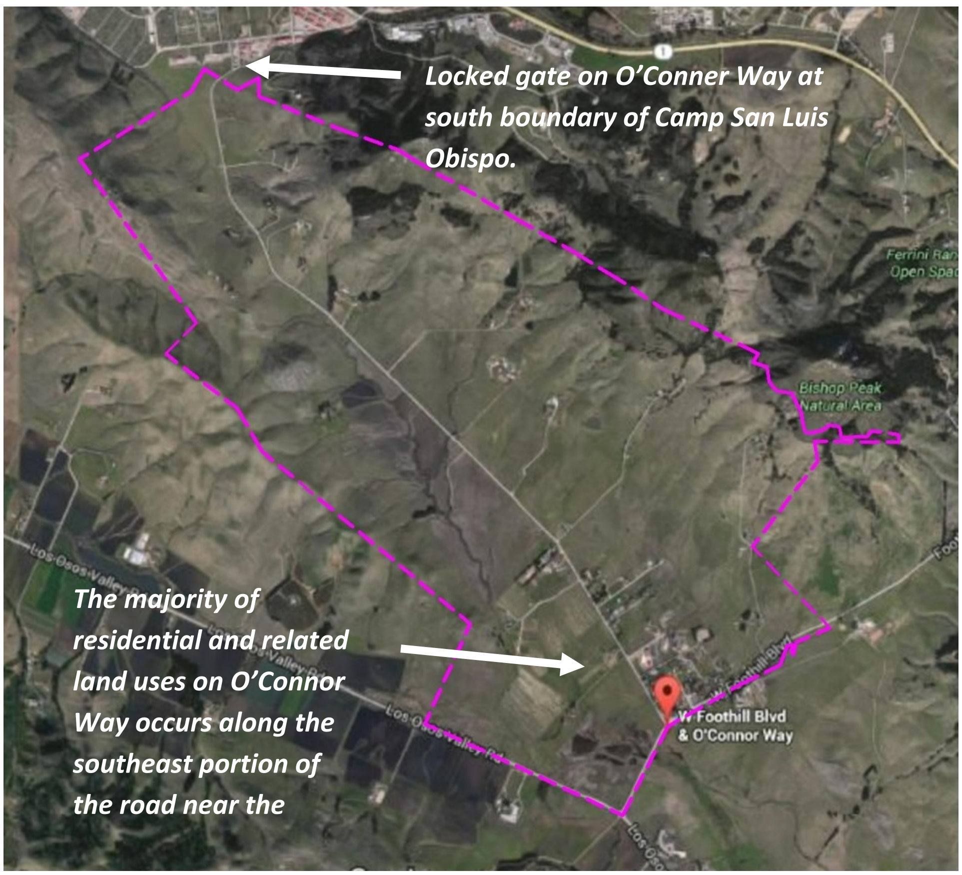
Revise Tentative Map with Design Modifications and Conditions of Approval Reflecting Fire Risk Mitigation Measures

Step 1

Step 1: Calculate Evacuation Time. Use the access tool (pre-programmed Excel spreadsheet) to estimate evacuation clearance time in minutes for proposed subdivision.

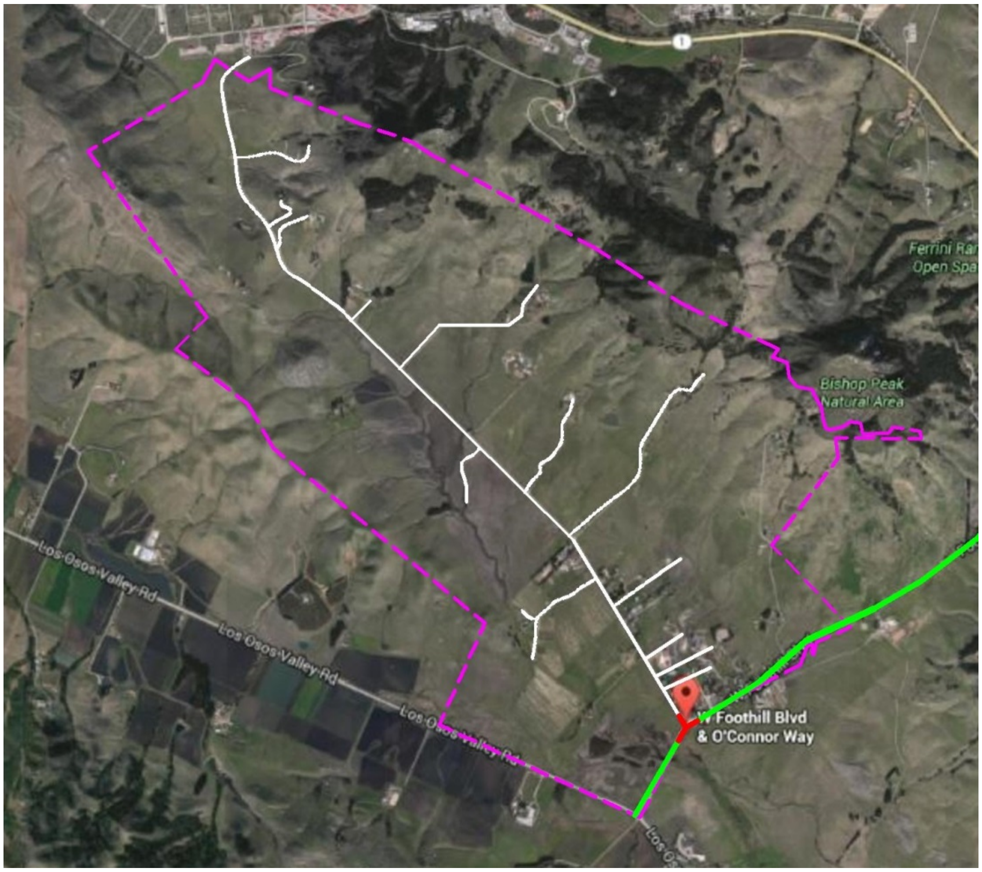
The following indicates how to estimate the time needed to evacuate an area using, **as an example**, details taken from the Foothill Boulevard and O'Connor Way case study (page 37 of this report). O'Connor Way is a dead-end road because its northerly outlet is blocked by a gate at the Camp San Luis Obispo California National Guard facility which closes it to through traffic. Figure 1-3 shows the entire Foothill Boulevard and O'Connor Way Case study area.

Figure 1-3: Foothill Boulevard and O'Connor Way Case Study Area



Intersecting with Foothill Boulevard near San Luis Obispo, O'Connor Way serves as an access spine for other dead-end streets as it extends northwest to Camp San Luis Obispo. Figure 1-4 shows this multiple dead-end street network.

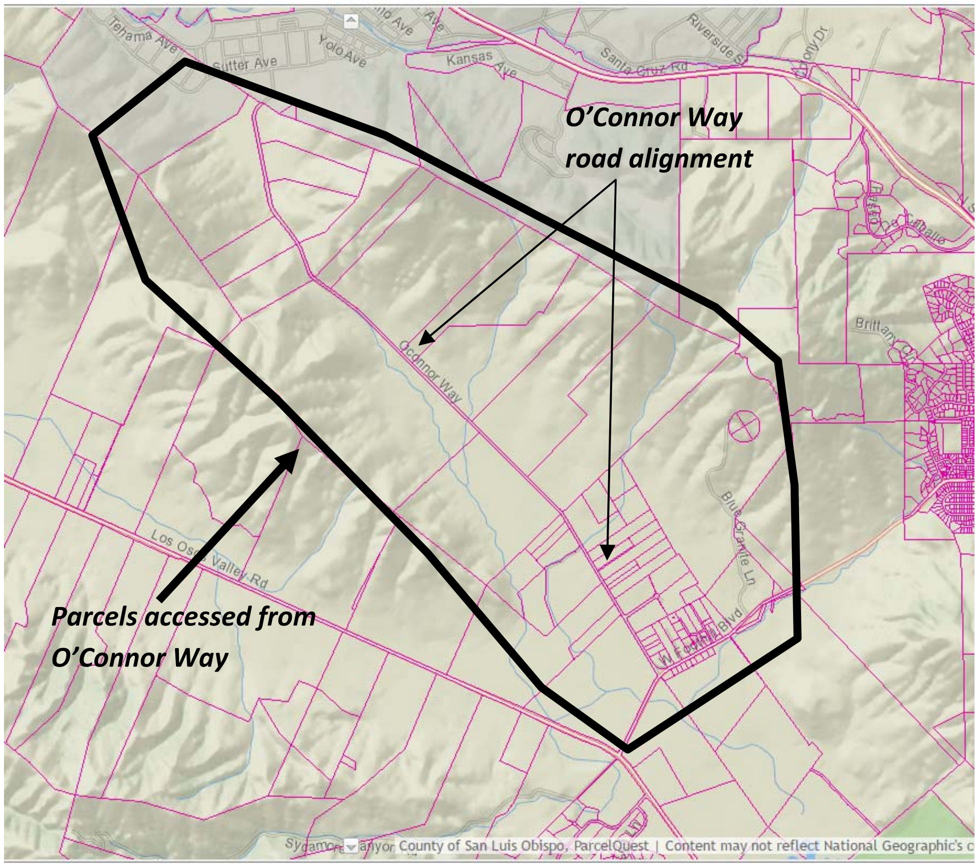
Figure 1-4: O'Connor Way Street Network



The O'Connor Way neighborhood is zoned rural residential and agriculture, and includes a mixture of comprising 95 homes, a school (120 persons occupancy), a church (400 persons occupancy), and a synagogue (200 persons occupancy). Most of these land uses are clustered near the southeast juncture with Foothill Boulevard.

Figure 1-5 on the following page illustrates each parcel accessed from O'Connor Way.

Figure 1-5: Parcels Accessed from O’Connor Way



1.1: Input data – From a street network map, input data into the access tool spreadsheet to prepare roadway schematic of development proposal or existing neighborhood with the following information, using the legend below and following the format shown in Figures 1-6 and 1-7:

1. Lengths of roadway segments (intersection-to-intersection in feet)
2. Directional lanes on roadway segments
3. Posted speed limit OR design speed (mph) on roadway segments
4. Number of houses (existing or proposed) on roadway segments
5. Other uses (retail, schools, churches, etc.) on roadway segments

LEGEND	
0.0	Length of segment (intersection to intersection in feet)
0.0	Number of houses on segment
0.0	Other uses on segment
	Subdivision roadway segment
	Potential bottlneck upon exit of development
	Nearby through road

Figure 1-6: Example of Roadway Schematic

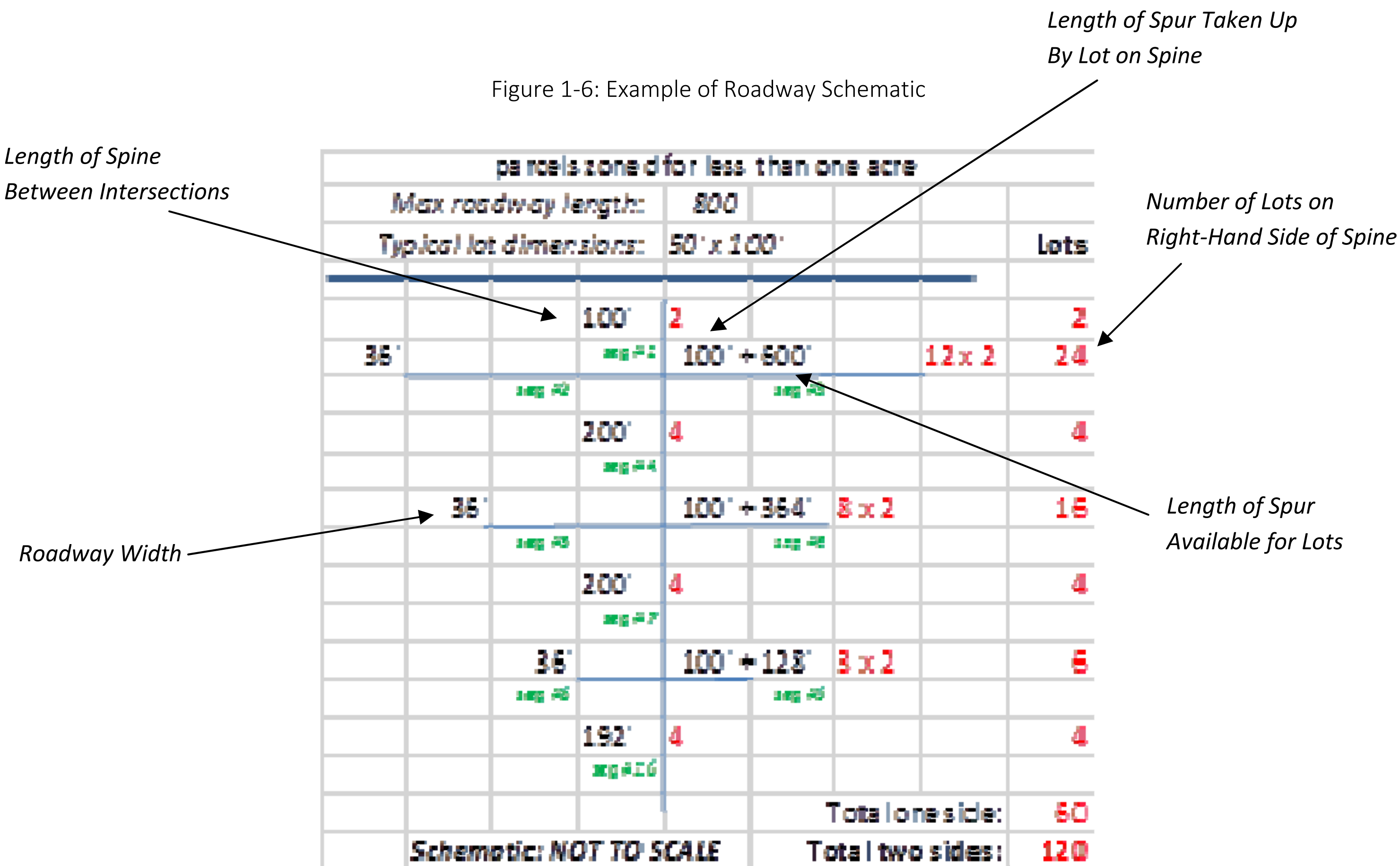
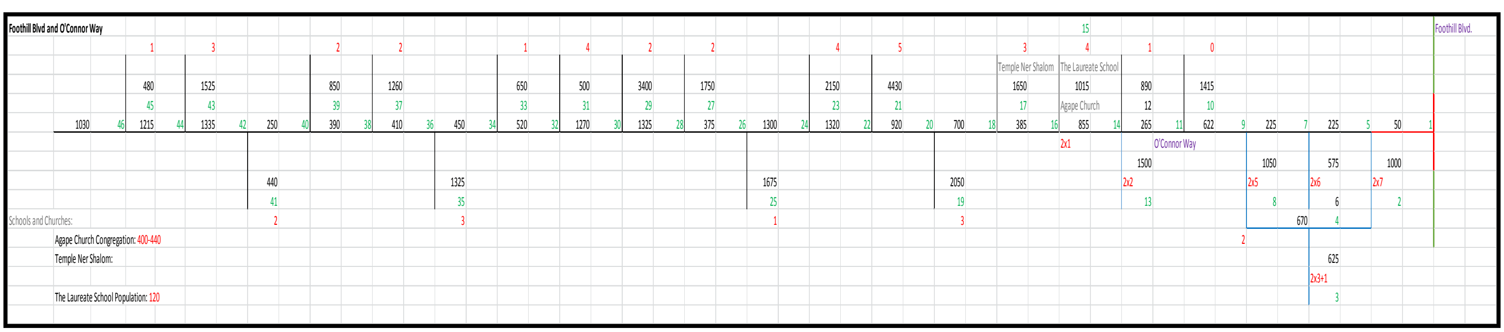


Figure 1-6 is a **simplified example** roadway schematic sample of a dead-end spine road with shorter dead-end roads branching from it. This example roadway schematic is shown in the access model spreadsheet. Figure 1-7 illustrates the roadway schematic created when entering the O'Connor Way data into the access tool spreadsheet

Figure 1-7: Roadway Schematic Created for Foothill Blvd and O'Connor Way

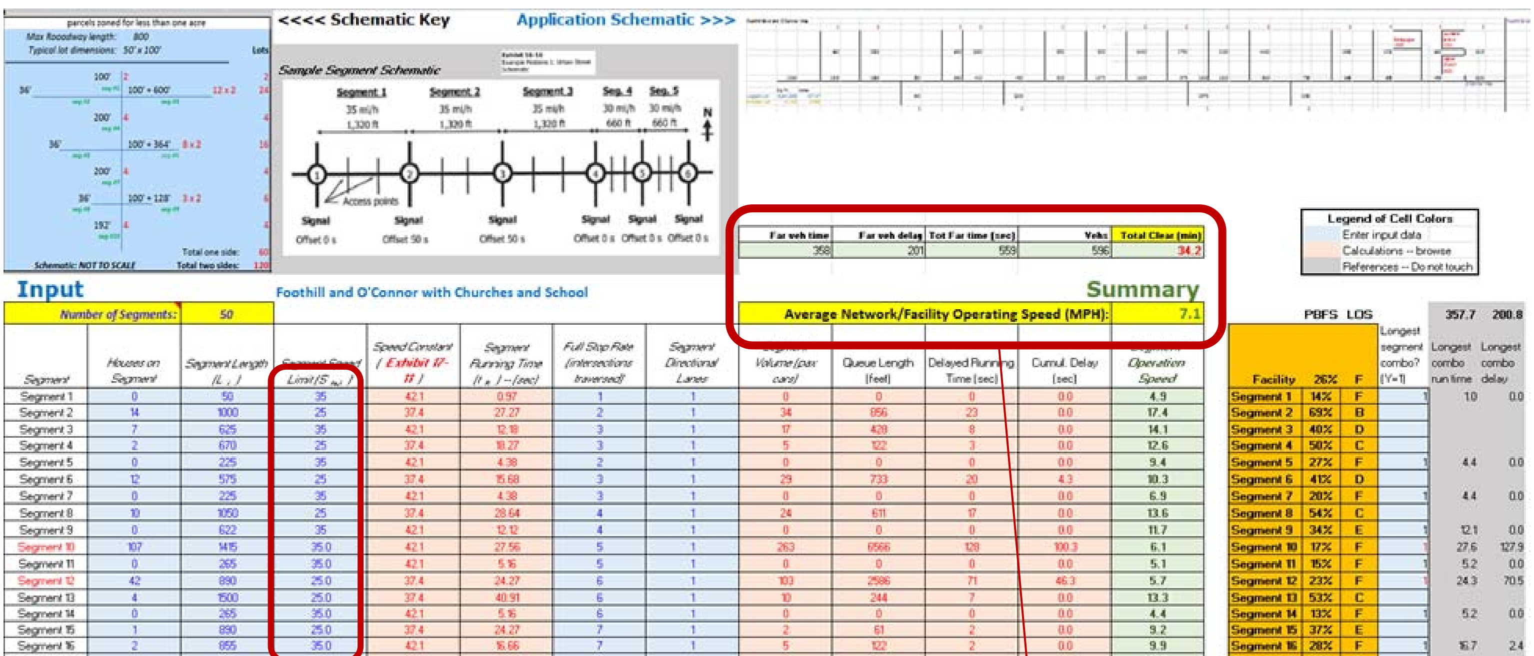


1.2: Calculate evacuation time – using the access tool spreadsheet:

1. Enter required data into blue cells for each roadway segment (number ID, length, speed, number of lanes, number of intersections to and including main road exit)
2. Read off results in green or yellow-highlighted cells (average travel time, clearance time)

Figure 1-8 illustrates the access tool spreadsheet calculating average travel time and clearance time for the Foothill Blvd and O'Connor Way case study. *(Refer to Appendix 2 for a full size copy of this schematic.)*

Figure 1-8: Access Tool Spreadsheet with O'Connor Way Inputs



Input data is entered in blue cells.

The output data in this portion of the tool are the modeling outcomes resulting from entry of input data in blue cells. Total clear time is listed in the green cell on the far right.

Step 2

Step 2: Estimate Fire Spread Rate - Use applicable vegetation-specific lookup tables to estimate fire spread rate with no mitigation.

> ***NOTE: It is recommended that a fire behavior expert be involved at various points in the procedure. For example, in executing Step 2, rather than using lookup tables (which are, of necessity, simplified) to estimate fire spread rate, greater accuracy might be achieved by asking an expert to do so instead. The expert should be a Registered Professional Forester with fire behavior expertise, retained by the local jurisdiction with CAL FIRE oversight.***

2.1: Determine Fire Behavior Inputs -

- Assign a fuel (vegetation) type using one of the four categories: ***grass, shrubs, coniferous forest, or broadleaf forest*** (detailed further in Section 4.0 and Appendix 3)
- Characterize topography and calculate average slope (for example, by using Cal Topo, https://caltopo.com/)
- Determine applicable wind speed (for example, by using Weather Underground, www.underground.com/history/)

The predominant vegetation type in the Foothill Blvd and O'Connor Way case study area is grassland. The images in Figure 1-9 show grassland vegetation examples

Figure 1-9: Vegetation Types in Foothill Blvd and O'Connor Way Case Study Area

Figures 1-10 and 1-11 shows steps to obtain average slope and wind speed from suggested websites. Other means may be used to obtain slope and wind speed information, if preferred.

Figure 1-10: Slope Calculation, Foothill Blvd and O'Connor Way Case Study Area

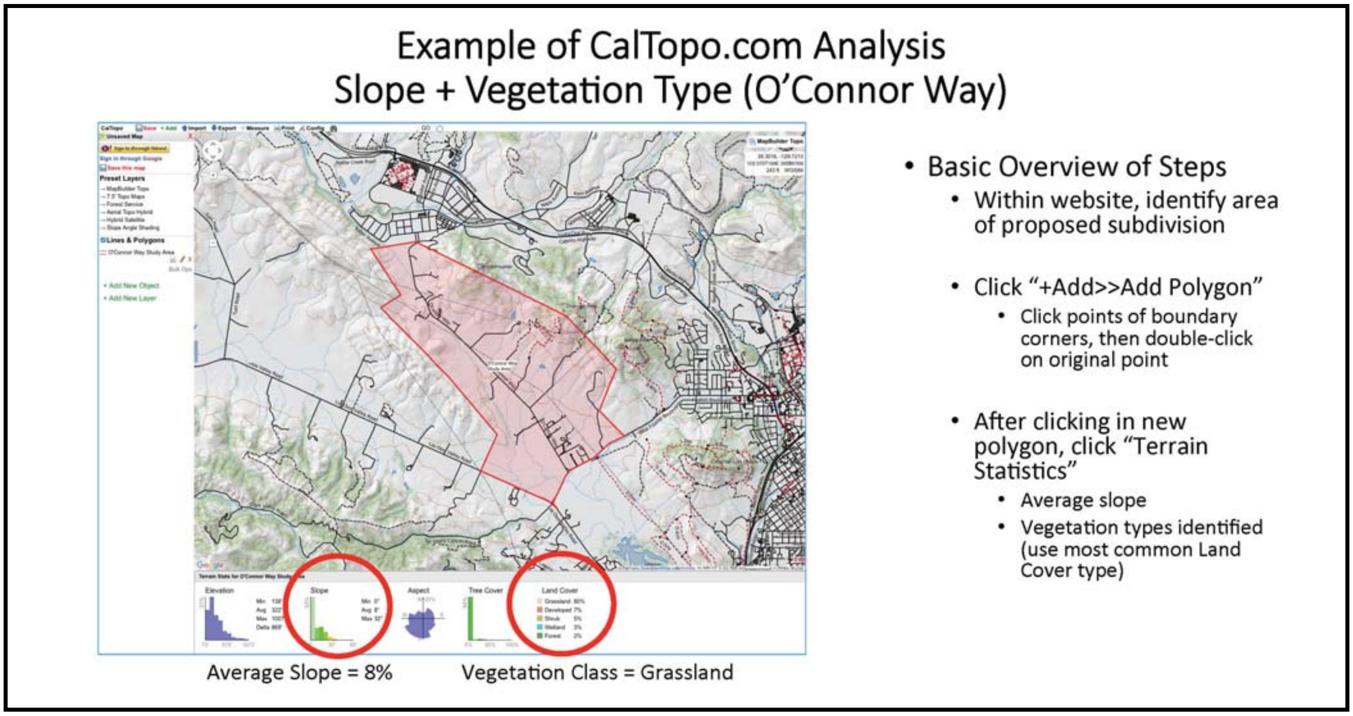
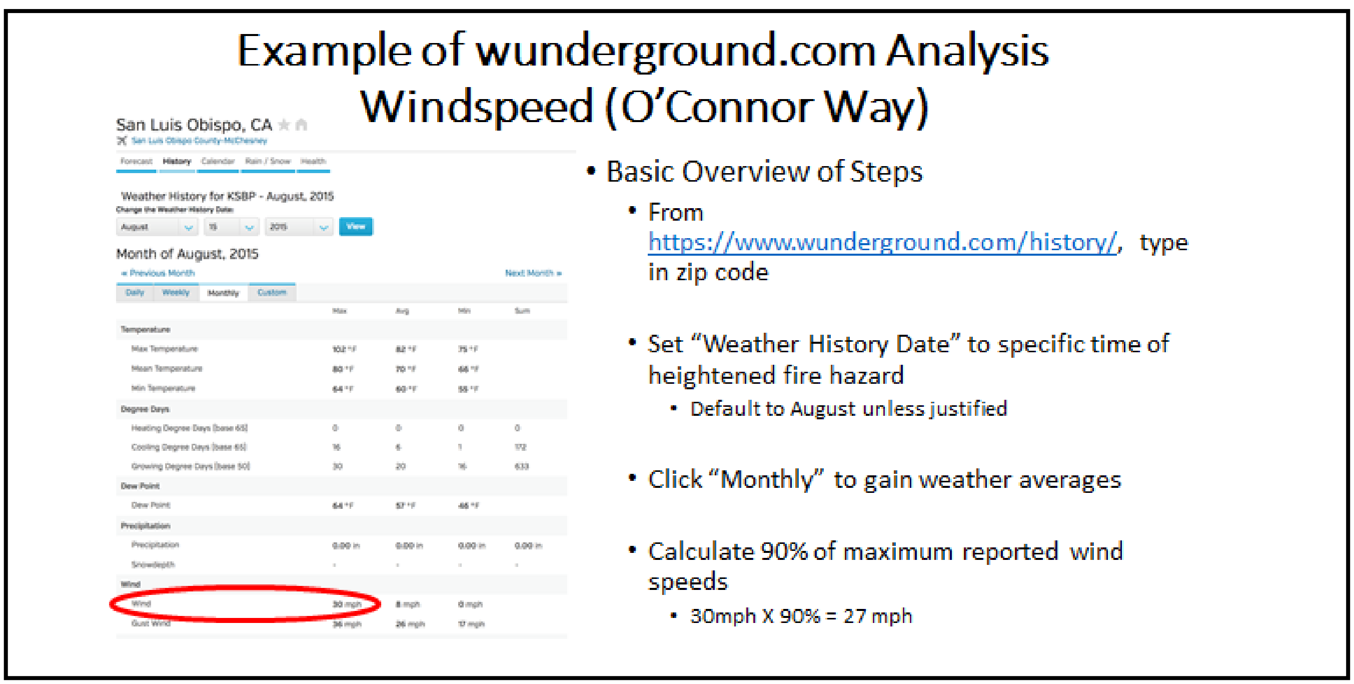


Figure 1-11: Wind Speed, Foothill Blvd and O'Connor Way Case Study Area



2.2 Estimate fire spread rate - Estimate the fire spread rate (feet per minute) using fire behavior l*ookup tables* (included in Appendix 3) with "No-Mitigation" and average wind speed.

Figure 1-12 illustrates use of the applicable look up table for unmitigated grassland and identifies the slope range of 1-25% and open wind speed of 30 mph for the Foothill Blvd and O'Connor Way case study area.

Figure 1-12: Lookup Table for Grasslands UNMITIGATED, Foothill Blvd and O'Connor Way Case Study Area

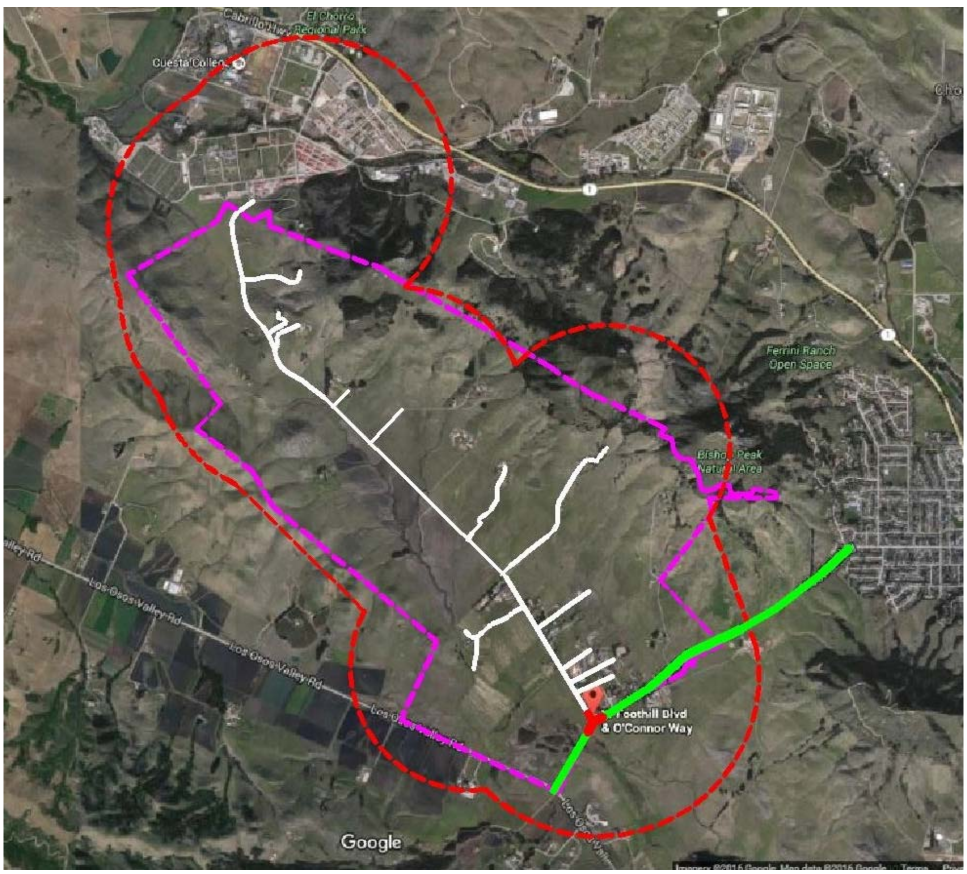
Vegetation: Grass						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 6'/min FL: 3'	ROS: 19'/min FL: 5'	ROS: 42'/min FL: 7'	ROS: 71'/min FL: 9'	ROS: 106'/min FL: 10'	ROS: 144'/min FL: 12'
1-25	ROS: 9'/min FL: 3'	ROS: 23'/min FL: 5'	ROS: 46'/min FL: 7'	ROS: 75'/min FL: 9'	ROS: 110'/min FL: 10'	ROS: 148'/min FL: 12'
26-40	ROS: 29'/min FL: 6'	ROS: 42'/min FL: 7'	ROS: 65'/min FL: 8'	ROS: 95'/min FL: 10'	ROS: 129'/min FL: 11'	ROS: 168'/min FL: 13'
41-55	ROS: 55'/min FL: 8'	ROS: 69'/min FL: 8'	ROS: 91'/min FL: 10'	ROS: 121'/min FL: 11'	ROS: 155'/min FL: 12'	ROS: 194'/min FL: 14'
56-75	ROS: 96'/min FL: 10'	ROS: 109'/min FL: 10'	ROS: 132'/min FL: 11'	ROS: 162'/min FL: 12'	ROS: 196'/min FL: 14'	ROS: 234'/min FL: 15'
>75	ROS: 159'/min FL: 12'	ROS: 173'/min FL: 13'	ROS: 196'/min FL: 14'	ROS: 225'/min FL: 14'	ROS: 260'/min FL: 15'	ROS: 298'/min FL: 16'

Step 3

Step 3: Determine Fire Risk Mitigation Envelope. The Fire Risk Mitigation Envelope is defined here as the area within which a fire burning is likely to compromise the ability of subdivision occupants to evacuate safely. It is delineated by calculating the distance a fire will spread in the evacuation clearance time and using this distance to establish an envelope around the evacuation routes. A fire outside this envelope will not have time to reach the evacuation routes before all occupants have exited from the subdivision.

3.1 Determine the Fire Risk Mitigation Envelope - Multiply evacuation clearance time (from Step 1) by the fire spread rate (from Step 2) to determine the Fire Risk Mitigation Envelope for evacuation routes. Draw this envelope around the subdivision roads.

Figure 1-13: Fire Risk Envelope UNMITIGATED, Foothill Blvd and O'Connor Way Case Study Area



3.2 Observe whether the Fire Risk Mitigation Envelope falls outside or within subdivision boundaries.

A. If the Fire Risk Mitigation Envelope is wholly within subdivision boundaries or study area, mitigation within the envelope is ***under the developer's or property owner's control***. By applying mitigation measures that reduce the fire rate of spread and/or the intensity, it should be possible for the developer to provide for subdivision occupants' safe evacuation from a fire starting inside or outside the subdivision.

B. If the Fire Risk Mitigation Envelope includes territory ***outside developer- or property owner-controlled land***, then it cannot be assumed that the developer or property owner would be able to apply appropriate mitigation measures to modify the fire rate of spread and/or intensity for the areas outside the subdivision. Consequently, a fire could compromise evacuation routes in less time than the clearance time.

Step 4

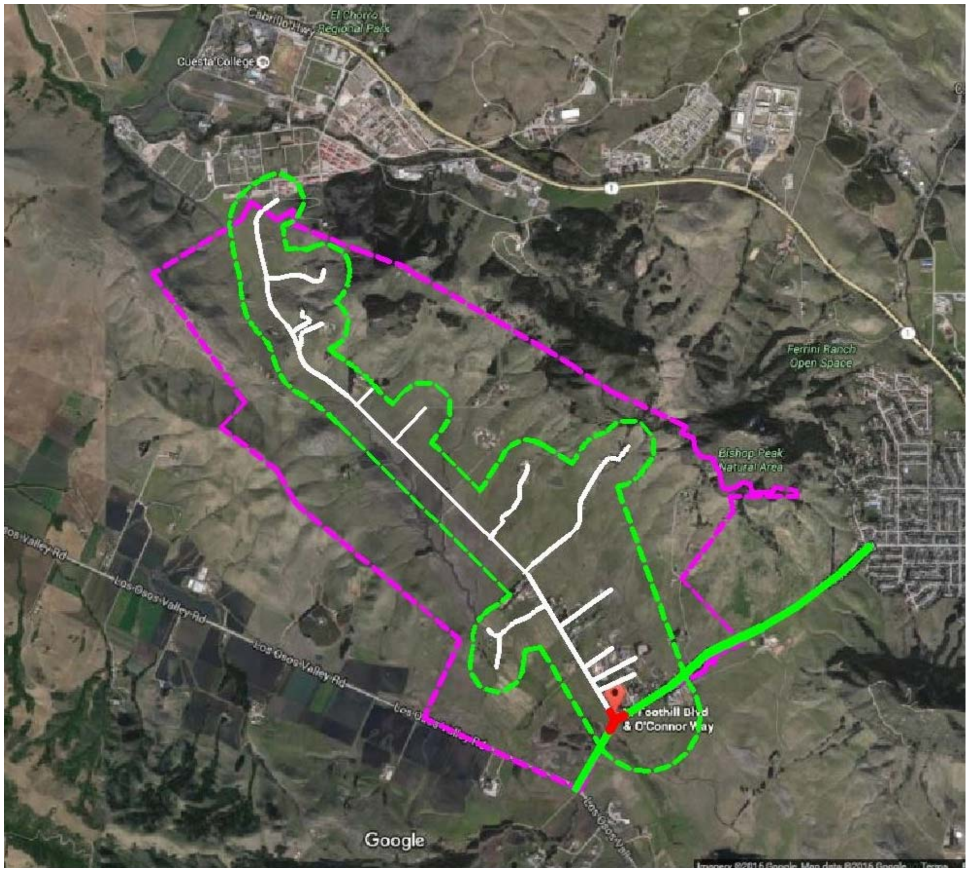
Step 4: Determine if Fuel Management Would Reduce Fire Risk Mitigation Envelope to Within Subdivision. Re-estimate the Fire Risk Mitigation Envelope using fire rate of spread derived from applicable vegetation-specific lookup table with mitigation to determine if mitigation measures addressing hazardous fuels would move the envelope wholly within the subdivision. [6]

Figure 1-14: Lookup Table for Grasslands MITIGATED, Foothill Blvd and O'Connor Way Case Study Area

Vegetation: Grass (Mitigated)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 1'/min FL: 0'	ROS: 4'/min FL: 1'	ROS: 9'/min FL: 2'	ROS: 15'/min FL: 3'	ROS: 23'/min FL: 4'	ROS: 30'/min FL: 5'
1-25	ROS: 2'/min FL: 0'	ROS: 5'/min FL: 1'	ROS: 10'/min FL: 2'	ROS: 16'/min FL: 3'	ROS: 23'/min FL: 4'	ROS: 30'/min FL: 5'
26-40	ROS: 7'/min FL: 2'	ROS: 9'/min FL: 2'	ROS: 14'/min FL: 3'	ROS: 21'/min FL: 4'	ROS: 28'/min FL: 5'	ROS: 35'/min FL: 5'
41-55	ROS: 7'/min FL: 3'	ROS: 9'/min FL: 3'	ROS: 14'/min FL: 4'	ROS: 21'/min FL: 4'	ROS: 28'/min FL: 5'	ROS: 35'/min FL: 6'
56-75	ROS: 22'/min FL: 4'	ROS: 25'/min FL: 4'	ROS: 30'/min FL: 5'	ROS: 36'/min FL: 5'	ROS: 44'/min FL: 6'	ROS: 51'/min FL: 7'
>75	ROS: 37'/min FL: 5'	ROS: 40'/min FL: 6'	ROS: 44'/min FL: 7'	ROS: 51'/min FL: 14'	ROS: 59'/min FL: 7'	ROS: 66'/min FL: 8'

[6] Again, greater accuracy might be achieved by employing a fire behavior expert rather than relying on the lookup tables

Figure 1-15: Fire Risk Envelope, MITIGATED, Foothill Blvd and O'Connor Way Case Study Area



Step 5

Step 5: Select Fire Risk Mitigation Measures and Subdivision Design Adjustments, as applicable.

5.1 If the Fire Risk Mitigation Envelope without mitigation extends outside the proposed subdivision or existing area beyond the developer's or property owner's control, at a minimum the local agency shall specify hazardous fuel mitigation measures to reduce the envelope (now re-estimated) so that, if possible, it falls wholly within the subdivision or area boundaries.

5.2 If hazardous fuel mitigation measures are inadequate to ensure that the Fire Risk Mitigation Envelope will fall within the subdivision or area boundaries, the local agency shall specify subdivision design adjustments or cooperative actions which can be taken by property owners, such as changes to the access layout (e.g., additional exits, more roadway lanes, etc.), size and numbers of lots, land uses, and/or development density in order to achieve this objective by effectively reducing the evacuation clearance time (which is an alternative way of shifting the Fire Risk Mitigation Envelope).

5.3 In complex situations the local agency should utilize the expertise of a fire behavior expert, as characterized above, to identify and determine the effectiveness of fire risk mitigation measures to be applied within the subdivision to ensure that all occupants can evacuate safely in the event of a fire starting within the Fire Risk Mitigation Envelope. Survivability should be possible if occupants begin leaving immediately upon becoming aware of the need to evacuate **and** if flame lengths are less than 4 feet and fire line intensity is less than 100 BTU/ft/sec.[7] (This is sometimes referred to as the "Hauling Chart" fire line intensity for a fire controllable using only hand tools).

5.4 In using recommendations of a fire behavior expert, ***if mitigation measures cannot achieve "the same practical effect" criterion*** of assuring "safe egress and ingress of occupants and fire personnel/equipment during a wildfire" then the tentative map ***cannot be approved***, unless and until an appropriate combination of fire risk mitigation measures can effectively meet that criterion.

Step 6

Step 6: Revise the Tentative Map with Design Modifications and Conditions of Approval Reflecting Fire Risk Mitigation Measures. Prepare a revised tentative subdivision map including specified design adjustments, conditions of approval, and tentative map findings consistent with Map Act, SB 1241 (2012), and PRC 4290.

[7] Patricia L. Andrews, Faith Ann Heinsch, and Luke Schelvan (2011), How to Generate and Interpret Fire Characteristics Charts for Surface and Crown Fire Behavior, General Technical Report RMRS-GTR-253. Logan, UT: United States Department of Agriculture, Forest Service, Rocky Mountain Research Station.

This page intentionally left blank

2.0 THE STUDY

Subdivision Map Approval Process

Standard land subdivision practice normally includes provision of at least two points of vehicle access to allow for safe egress of occupants and efficient ingress by responders in case one point is blocked in an emergency. Where terrain, property ownerships, or other constraints make only a single access feasible, with all parties using one dead-end road, it is important to take special precautions to minimize risk in an emergency.

When a wildfire threatens a single-access subdivision, potentially life-threatening problems may arise when occupants seek to evacuate to a safe location while fire and other responders try to manage the emergency. Even when access is not disrupted by fire or smoke, factors such as inadequate road widths, steep grades, traffic congestion, and obstacles in the road can interfere with safe and timely in- and out-movement, possibly causing entrapment of occupants and preventing responders from gaining access to do their job.

Under California's Subdivision Map Act (known as the "Map Act"), authority is given to cities and counties to regulate and control the subdivision of real property (see Figure 1-1 in Section 1.0 for example of typical subdivision map). The statute specifies two steps for the approval of a new subdivision: (1) tentative map approval, which determines the overall subdivision design and improvements; and (2) final map approval. The second step is a purely ministerial process, meaning that the final map is automatically approved once stated terms and conditions have been met.

In the first step, the tentative map is reviewed by the locally designated "advisory agency," which can be at any level as determined by the governing body. Many localities delegate this process primarily to staff, so the review is conducted by a committee composed of representatives of planning, engineering, fire, and other interested departments. Staff determinations are generally subject to review at a higher level such as the planning commission and/or board of supervisors or city council.

Under the Map Act, tentative map approval requires that certain mandatory findings be made for the record. One of these mandatory findings is that the tentative map, including its design and improvements, is consistent with the general plan.[8] Tentative map approval is a discretionary action under the California Environmental Quality Act (CEQA), requiring a Mitigated Negative Declaration (MND) or an Environmental Impact Report (EIR), depending on size and impact of the proposed subdivision. Tentative map conditions are the primary means used to ensure the implementation of mitigation measures identified in the MND or EIR before the final map is recorded.

Under the provisions of recent legislation (cited in Section 1.0), for tentative map approval to be granted

---

[8] Government Code Section 66473.5.

to a proposed subdivision in an area located within a State Responsibility Area (SRA)[9] or a locally adopted Very High Fire Hazard Severity Zone (FHSZ), the following findings beyond those required by the Map Act must be made: (1) that the design and location of the subdivision are consistent with applicable regulations adopted by the State Board of Forestry and Fire Protection (the "Board") pursuant to Sections 4290 and 4291 of the Public Resources Code (PRC), (2) that structural fire protection and suppression services will be available for the subdivision, and (3) that, to the extent practicable, ingress and egress for the subdivision meet the regulations regarding road standards for fire equipment access adopted pursuant to PRC Section 4290 and any applicable local ordinance.

The existing standards governing the maximum lengths of dead-end roads, promulgated under PRC Section 4290, were described in Section 1.0, as were the shortcomings resulting from the fact that the existing standards depend only on parcel sizes allowed by zoning; they fail to take into account a variety of other factors affecting egress and ingress.

Purpose and Methodology of Study

As stated in Section 1.0, this study was intended to assess the current standards, to provide a defensible foundation for establishing new standards if needed, and to develop a simple-to-use planning tool based on computer modeling that can be applied by jurisdictions, developers, and others to (1) judge whether a project proposal is likely to satisfy the "same practical effect" criterion meant to meet the regulatory intent of assuring "safe egress and ingress of occupants and fire personnel/equipment during a wildfire," and (2) assist them in identifying mitigation options that will enable this criterion to be met.

Because of the nature of the tentative map approval process described above, the planning tool was designed so that informed non-technical participants (such as members of the public, the planning commission, the board of supervisors, or the city council) would be able to use it without having to seek the advice of an expert -- although greater accuracy might be expected to result from the use of a fire behavior expert, in particular. The non-technical user would be able to enter relevant information and receive understandable results, with the calculations proceeding in the background. By changing the inputs, the user would be able to test different scenarios (e.g., alternative mitigation strategies).

In the context of a wildfire occurrence, access involves four phases of activity: discovery, notification, reaction, and travel. In this project the team focused only on the travel phase. The other three phases are highly variable and would typically precede the fourth phase. In a worst case, all four phases could occur in quick succession, but the travel phase would always be at the tail end of the activities.

The team set out to develop a prototypical access planning and evaluation tool ("the tool") that would allow the user to estimate the time (T) needed for evacuation of occupants from a single- access

[9] PRC Section 4102 defines SRAs as "areas of the state in which the financial responsibility of preventing and suppressing fires" is "primarily the responsibility of the state."

subdivision threatened by a fire to an intersection with a through road,[10] and/or ingress of emergency response personnel/equipment to the fire's location, as a function of key variables or combinations thereof (KV1, KV2, KV3, etc.).

$$T = f(KV1, KV2, KV3, \ldots)$$

Initially, the key variables to be included in the underlying model were to be drawn from the following four groups of factors or combinations thereof:

- Proposed land use
- Demographic composition of proposed development
- Road system characteristics
- Fire behavior

As it turned out, the team was unable to incorporate fire behavior as a variable **directly** into a model that could be applied by those who are not themselves fire behavior experts. Nevertheless, as discussed later in this report, the team was able to develop a means by which planners and others may choose to combine the results of applying the tool with information about the likely rate of spread and intensity of a wildfire.

Egress

As ultimately developed, the tool estimates how quickly occupants can leave a subdivision as a function of:

- Intensity of development or number of people to evacuate (expressed in number of vehicles);
- Physical size of development or distance to traverse;
- Potential travel speed for the given design speed of segments in the road network; and
- Design speed of roadway segments.

The tool is designed to handle up to 250 roadway segments in one application.

The tool's input screen is designed to be user-friendly, allowing the entry of simple information such as the proportion of different land use types being proposed (e.g., single-family residential, multi-family residential, school, commercial, etc.). The tool estimates the number of persons associated with the land use types and sizes, based on default values. However, each agency having jurisdiction can enter its own values.

[10] The structural fire protection engineering equivalent of this time is the Actual Safe Egress Time (ASET). ASET is the actual time for occupants to reach a "safe place."

Ingress

The team also explored the possibility of incorporating into the tool the time needed for emergency response personnel/equipment to reach the fire's location. The intention was to use data for response times of emergency responders that were supplied by CAL FIRE for the past 5 years.

However, ultimately the team decided not to incorporate response times into the tool in its present iteration, in part because of a lack of confidence that the currently available data accurately reflect what the team was trying to measure. One of the problems is the uncertainty about the location of CAL FIRE vehicles when response time measurements are initiated (i.e., the vehicles may not start out from a fire station and/or they may already be on their way to a fire when they report that they are responding). Furthermore, for the purpose of this study, the assumption was made that the safe evacuation of occupants is typically the first priority.

3.0 Access Modeling

Methodology for Applying the Tool

Input Data

The application of the access model requires the conversion of a subdivision (whether existing or proposed) into a schematic of links (or roadway segments) and nodes (or intersections). At a minimum, the information needed along each link includes:

1. Length of link (feet)
2. Number of directional lanes
3. Posted speed limit ***or*** design speed (in miles per hour [mph])
4. Number of houses and other land uses (existing or proposed)

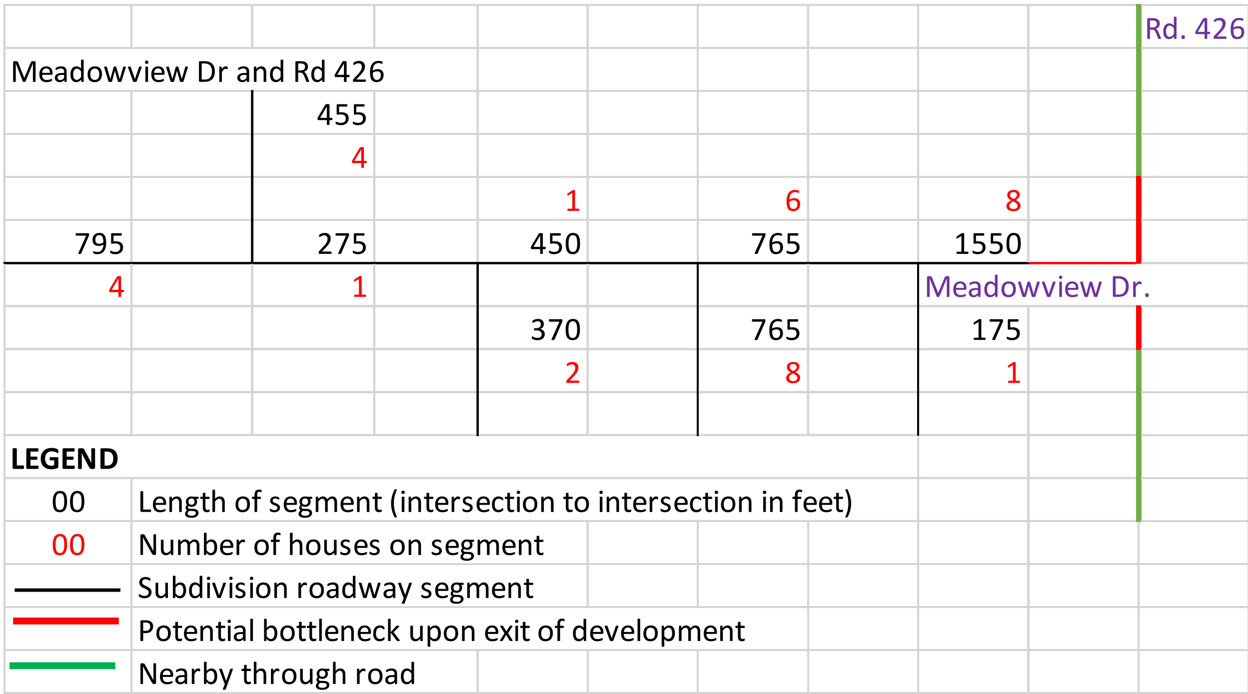
Figure 3-1 illustrates a sample subdivision network, with its roadway schematic shown in Figure 3-2. Appendix 2 (Additional Details on Access Modeling) includes additional examples of applications.

Figure 3-1: Sample Subdivision Network

LEGEND

(black line)	Subdivision roadway segment
(red line)	Potential bottleneck upon exit of development
(green line)	Nearby through road

Figure 3-2: Roadway Schematic for Sample Subdivision Network



Additional information required for background calculations of ***roadway capacity*** includes:

1. Lane width (feet)
2. Shoulder width (feet)
3. Access-point density (that is, number of intersections on one side of the street per mile)
4. Terrain (level, rolling)
5. Percent no-passing zone (20%, 40%, 80%)
6. Length of passing lane (if present)

Capacity Calculation

The calculation of roadway capacity is a multi-step process involving Highway Capacity Methods of the 2010 Highway Capacity Manual (HCM).[11] Procedures are adapted from Chapter 15 of the 2010 HCM. Appendix 2 (Additional Details on Access Modeling) includes details.

[11] The HCM is a publication of the Transportation Research Board of the National Academies of Science. Engineers and planners use the HCM to assess the traffic and environmental effects of highway projects.

Speed and Travel Time Calculation

The calculation of vehicle speed and travel time is a multi-step process involving Highway Capacity Methods of the 2010 HCM. Procedures are adapted from Chapter 16 of the 2010 HCM. Appendix 2 (Additional Details on Access Modeling) includes details.

Total Travel Time

The total travel time involved in evacuating occupants in vehicles from a single-access subdivision on to a through road[12] is made up of:

1. The nominal time to clear all vehicles out of the development (Clearance Time); ***plus***
2. The sum of any delays encountered by individual vehicles as they approach the intersection with the through road (estimated using HCM methods).

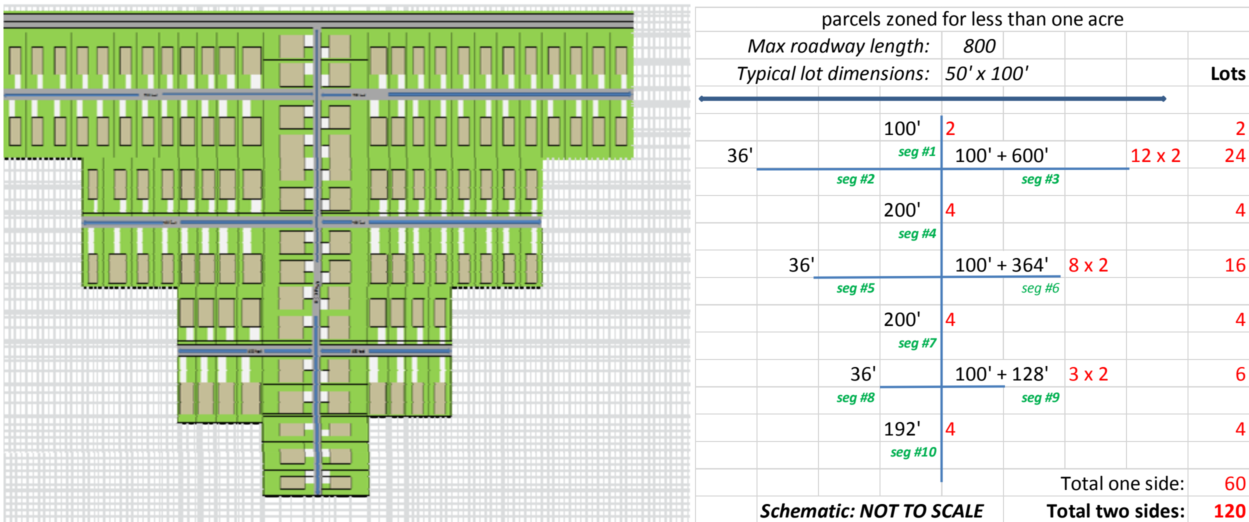
Initial Assessment of Existing Standards

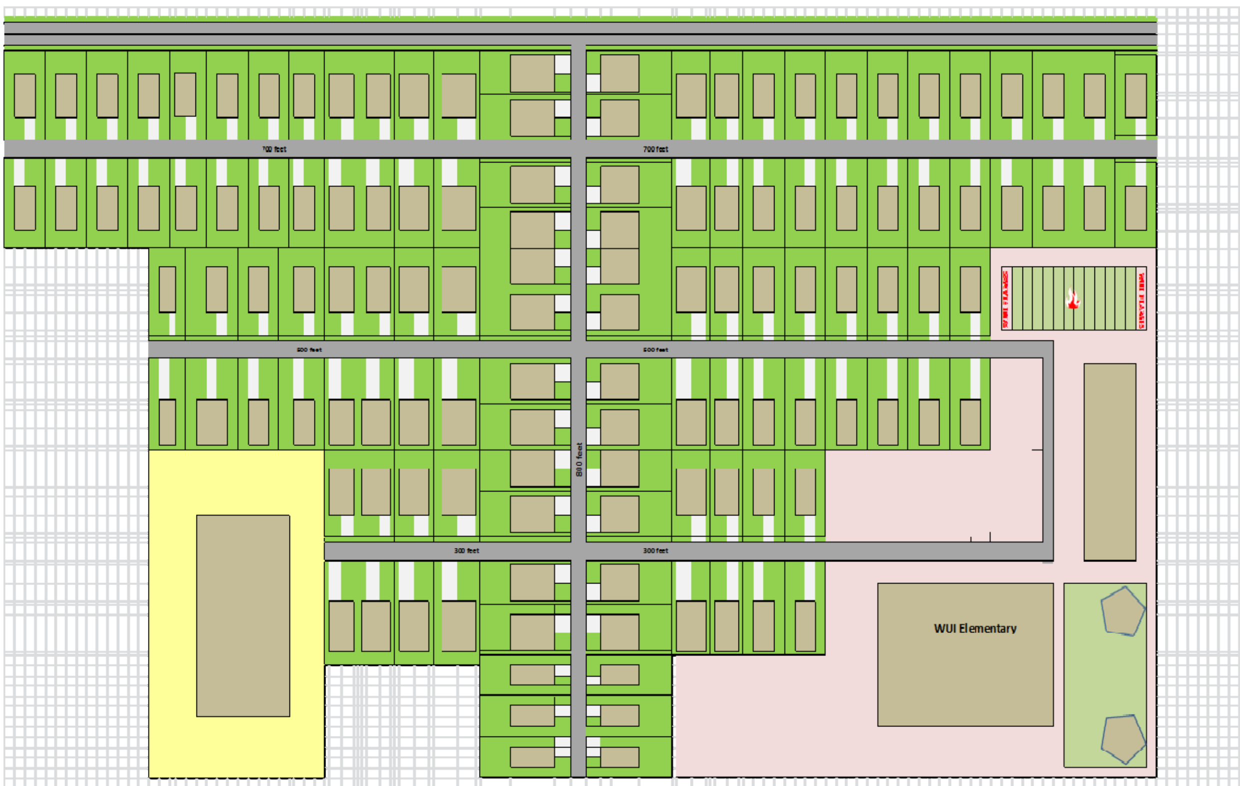
Hypothetical Configurations

The team first considered how many parcels within a particular size category (less than 1 acre, 1 to 4.99 acres, etc.) can fit along the prescribed dead-end road maximum lengths, using various plausible but hypothetical configurations. For example, where zoning allows parcels of less than 1 acre, the standards allow a dead-end road to reach a maximum of 800 feet ***including cumulative lengths of dead-end roads accessed from the main dead-end road***. In other words, the standards allow one or more forks along the dead-end road and along the forks themselves (a condition known as "stacking"), provided that the length of the road from the far end of ***any*** fork does not exceed the prescribed maximum. Using the configurations illustrated in Figure 3-3 for a subdivision with parcels of less than 1 acre, it would be possible to comply with the standards with as many as 120 parcels in such a subdivision. For subdivisions with parcels between 1 acre and 5 acres, Figure 3-4 illustrates that it would be possible to comply with the standards with as many as 46 parcels. For subdivisions with parcels between 5 acres and 20 acres, it would be possible to comply with the standards with as many as 34 parcels, as illustrated in Figure 3-5. For subdivisions with parcels greater than 20 acres, it would be possible to comply with the standards with as many as 36 parcels, as shown in Figure 3-6.

[12] As previously noted in footnote 7, the evacuation of occupants on to a through road may not by itself ensure their safety.

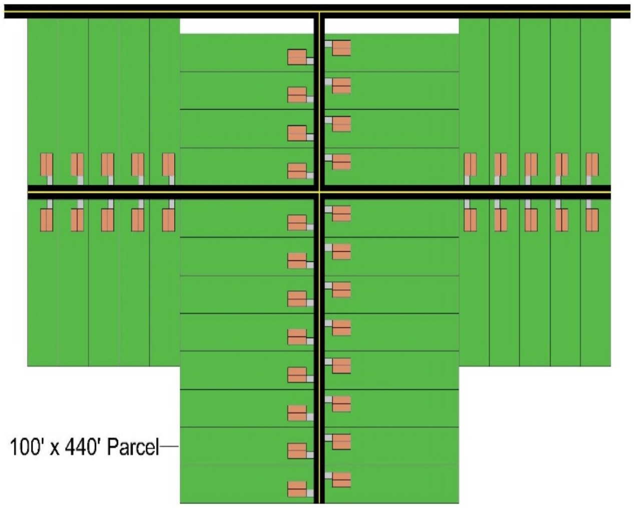
Figure 3-3: Sample Subdivision Network with Parcel Size of Less than 1 Acre



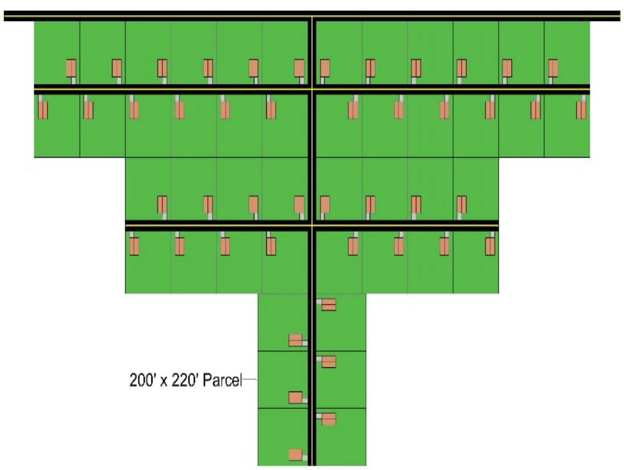


Maximum of 800 feet including cumulative lengths of dead-end roads accessed from main dead-end road. Upper image includes housing only; lower image includes housing and a school.

Figure 3-4: Sample Subdivision Network with Parcel Size of 1 to 5 Acres



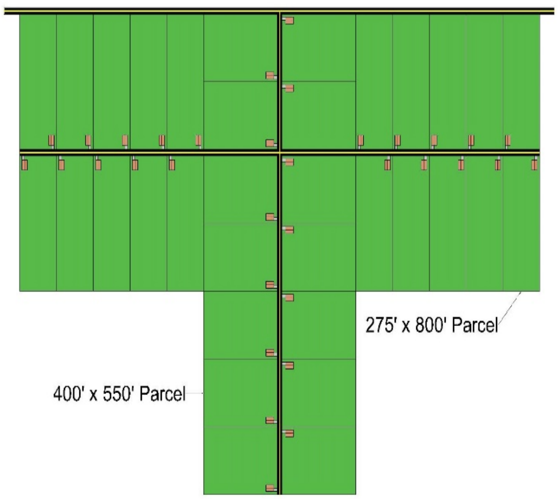
parcels zoned for 1 acre to 4.99 acres				
Max roadway length:	*1320*			
Typical lot dimensions:	*100' x 440'*			**Lots**
440'	4			4
36'		440' + 440'	5 x 2	10
440'	4			4
404'	4			4
			Total one side:	22
Schematic: NOT TO SCALE			**Total two sides:**	**44**



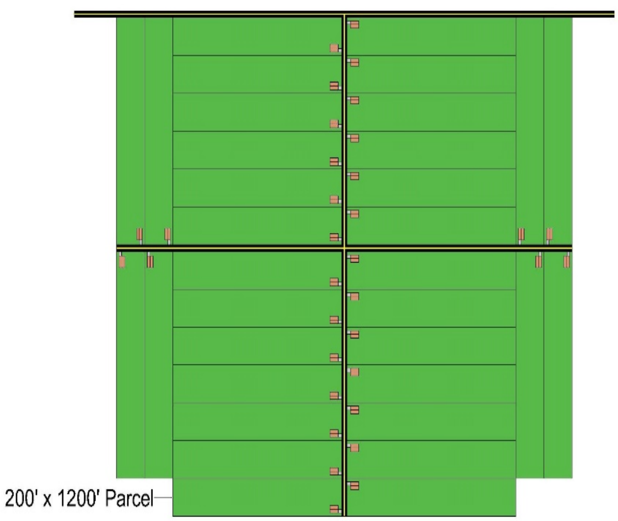
parcels zoned for 1 acre to 4.99 acres				
Max roadway length:	*1320*			
Typical lot dimensions:	*200' x 220'*			**Lots**
220'	0			0
36'		200' + 900'	6 x 2	12
440'	0			0
36'		200' + 424'	4 x 2	8
588'	3			3
				0
			Total one side:	23
Schematic: NOT TO SCALE			**Total two sides:**	**46**

Maximum of 1,320 feet including cumulative lengths of dead-end roads accessed from main dead-end road.

Figure 3-5: Sample Subdivision Network with Parcel Size of 5 to 20 Acres



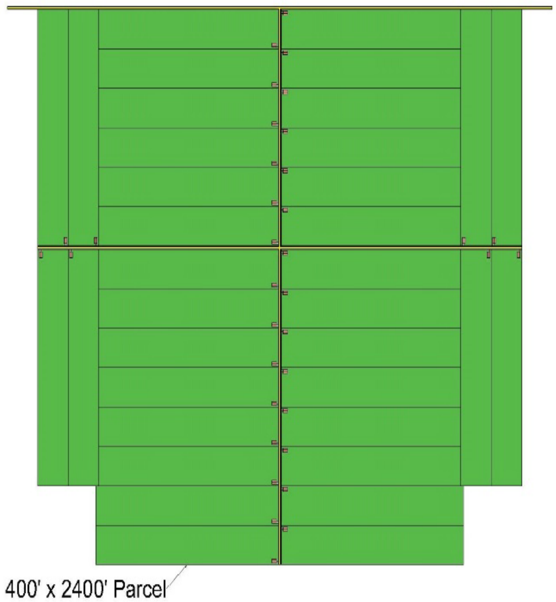
parcels zoned for 5 acres to 19.99 acres					
Max roadway length:	*2640*				
Typical lot dimensions:	*400' x 550' & 275' x 800'*				**Lots**
	800'	2			2
36'			550' + 1290'	5 x 2	10
	800'	2			2
	800'	2			2
	204'	1			1
				Total one side:	17
Schematic: NOT TO SCALE				**Total two sides:**	**34**



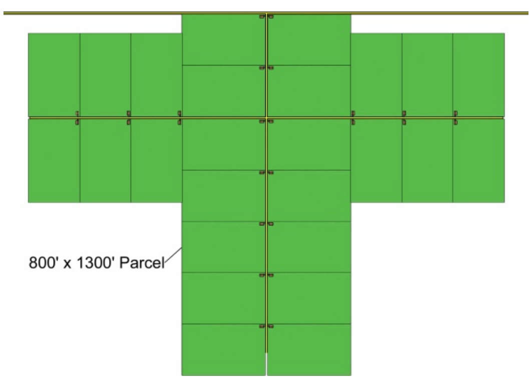
parcels zoned for 5 acres to 19.99 acres					
Max roadway length:	*2640*				
Typical lot dimensions:	*200' x 1200'*				**Lots**
	1200'	6			6
36'			1200' + 240'	2 x 2	4
	1200'	6			6
	204'	1			1
				Total one side:	17
Schematic: NOT TO SCALE				**Total two sides:**	**34**

Maximum of 2,640 feet including cumulative lengths of dead-end roads accessed from main dead-end road.

Figure 3-6: Sample Subdivision Network with Parcel Size of 20 Acres or Larger



parcels zoned for 20 acres or larger								
Max roadway length:				*5280*				
Typical lot dimensions:				*400' x 2400'*				**Lots**
			2400'	6				6
36'				2400' + 480'			2 x 2	4
			2400'	6				6
			444'	2				2
							Total one side:	18
	Schematic: NOT TO SCALE						**Total two sides:**	**36**



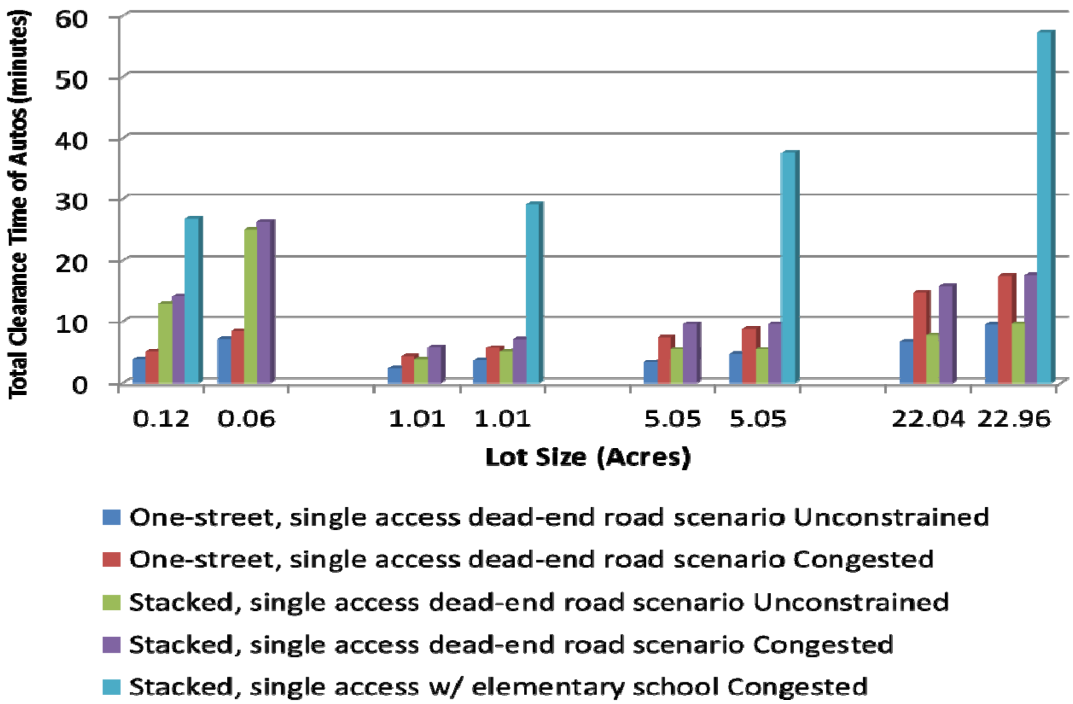
parcels zoned for 20 acres or larger								
Max roadway length:				*5280*				
Typical lot dimensions:				*800' x 1300'*				**Lots**
			1600'	2				2
36'				1300' + 2380'			3 x 2	6
			3200'	4				4
			444'	1				1
							Total one side:	13
	Schematic: NOT TO SCALE						**Total two sides:**	**26**

Maximum of 5,280 feet including cumulative lengths of dead-end roads accessed from main dead-end road.

Results of Initial Assessment

The team next examined hypothetical scenarios conforming to parcel-size categories and estimated the time for clearing all vehicles from a subdivision (egress time - T). Figure 3-7 presents a graphical comparison of the results, along with the associated data table.

Figure 3-7: Comparative Times to Clear Occupants under Various Lot Configurations



Lot Size (acres)	Land Use	Zoned (acres per DU)	Private Auto Clearance Times (mins): One-street, single access dead-end road scenario		Stacked, single access dead-end road scenario		Stacked, single access w/ elementary school
			Unconstrained	Congested	Unconstrained	Congested	Congested
0.12	SFR (50' x 100')	< 1	4	5	13	14	27
0.06	SFR (25' x 100')	< 1	7	8	25	26	
1.01	SFR (200' x 220')	1 to 4.99	2	4	4	6	
1.01	SFR (100' x 440')	1 to 4.99	4	6	5	7	29
5.05	SFR (400' x 550')	5 to19.99	3	7	6	10	
5.05	SFR (200' x 1100')	5 to19.99	5	9	6	10	38
22.04	SFR (400' x 2400')	20+	7	15	8	16	
22.96	SFR (200' x 5000')	20+	9	17	10	18	57

DU= dwelling unit

Times in excess of 10 minutes are written in red.

In Figure 3-7, "unconstrained" situations indicate no additional travel delay from network congestion or poor visibility. "Congested" situations indicate drastic reduction in average network speed as a result of capacity and visibility constraints on movement.

The findings were as follows:

- In relatively good conditions (e.g., no congestion or no visibility constraints), egress time was sometimes but not always less than 10 minutes.

- Subdivision configurations with the smallest and largest parcels showed the greatest potential for problems with evacuation. In subdivisions with the smallest parcels, assuming that developers will typically construct as many residential units as possible in a bid to maximize return on investment, large numbers of residents potentially will have to be evacuated. In subdivisions with the largest parcels, residential units will be spread out, creating long traverse distances during evacuation. These results illustrate the flaw in the language of the existing standards ("*regardless of the number of parcels served*") that permits the size of development and the number of occupants to be ignored.

- Scenarios involving unconstrained conditions depicted the best possible results, but these conditions are not thought likely to occur under emergency conditions. Scenarios involving congested conditions depicted more likely results, but even these scenarios still assumed that there would be no obstruction (bottleneck) where the single-access road exits on to a through road. The existing standards do not address the potential for bottlenecks.

- The problems are likely to be most severe when land use is not limited to single-family residential. Condominiums, mobile home parks, campgrounds, retail commercial, schools, and churches are among the other, more intense forms of development that can occur. In these types of development, many more people may need to be evacuated in a fire emergency, for example if a school is in session or a church service is being held. This observation illustrates a further flaw in the existing standards, which ignore the type of development that is being proposed as well as the possibility that the intensity of land use will change over time.

Case Studies

The tool was applied in 14 case studies including 1 hypothetical case, 12 existing cases, and 1 proposed case. The cases were selected to enable assessment of a variety of access situations in the wildland-urban interface, including subdivisions with single or multiple access, residential or other land uses (such as schools and churches), and/or problematic connections to arterials or other through roads. One case allowed the team to explore the potential effect of smoke from a wildland fire. Prior familiarity with locations ultimately dictated the case selections, which resulted in the following geographic distribution: three cases in Santa Barbara County, seven cases in San Luis Obispo County, one case in Madera County, one case in Contra Costa County, and one case in Placer County. Figure 3-8 identifies the geographic locations of the case studies.

Table 2-1 provides a summary of results from applications of the tool. The figures that follow show the road networks (in light-colored lines) within the case study subdivisions and demarcate the exit points, which are potential bottlenecks (shown in red). The figures also show the through roads for evacuation (in green). A subsequent section provides an overview of the results.

Figure 3-8: Geographic Locations of Case Studies

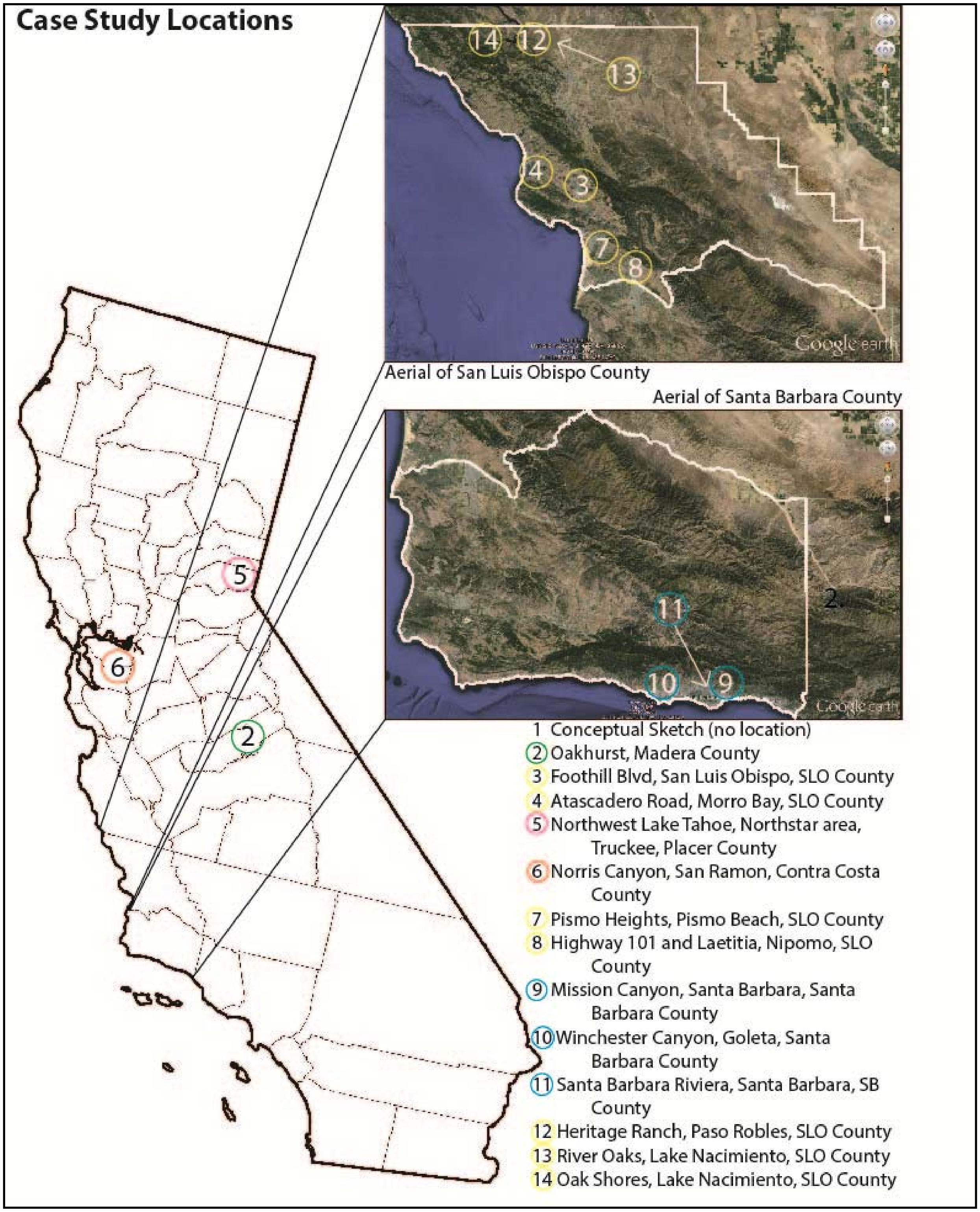


Table 3-1: Application of Tool to Case Studies – Summary of Results

Case	Case Study *(Residential Developments except as otherwise noted)*	Farthest Vehicle Time (seconds)	Farthest Vehicle Delay (seconds)	Total Farthest Time (seconds)	Vehicles to Clear Out	Average Network/Facility Operating Speed (mph)	Total Clearance Time (minutes)
1	Stacked Single-Access – conceptual sketch only	22	47	68	293	7	13
2	Oakhurst: Meadowview Drive and Road 426, Madera County	105	33	138	86	12	6
3	Foothill Boulevard and O'Connor Way, San Luis Obispo County (*Mixed use development: Homes, School , Churches*)	367	248	615	466	8	30
4	Atascadero Road and Mission Drive, Morro Bay, San Luis Obispo County	33	33	66	315	5	14
5	Northwest Lake Tahoe, Truckee, Placer County	730	8	738	1,621	8	80
6	Norris Canyon Estates, San Ramon, Contra Costa County	323	200	523		9	42
7	Pismo Heights, Pismo Beach, San Luis Obispo County	217	200	417	1,149	6	55
8	Highway 101 and Laetitia Vineyard Drive, Nipomo, San Luis Obispo County (*Proposed development*)	376	27	402	247	15	17
9	Mission Canyon, Santa Barbara, Santa Barbara County	190	23	214	853	13	39
10	Winchester Canyon, Goleta, Santa Barbara County	475	17	492	369	16	24
11	Santa Barbara Riviera, Santa Barbara, Santa Barbara County	340	0	340	848	14	41
12.1	Heritage Ranch – Western Entrance, Paso Robles, San Luis Obispo County	255	0	255	1,435	4	64
12.2	Heritage Ranch – Eastern Entrance, Paso Robles, San Luis Obispo County	765	33	799	2,476	6	117
13	River Oaks, Lake Nacimiento, San Luis Obispo County	122	37	159	264	17	14
14	Oak Shores, Lake Nacimiento, San Luis Obispo County	44	50	94	1,569	9	67

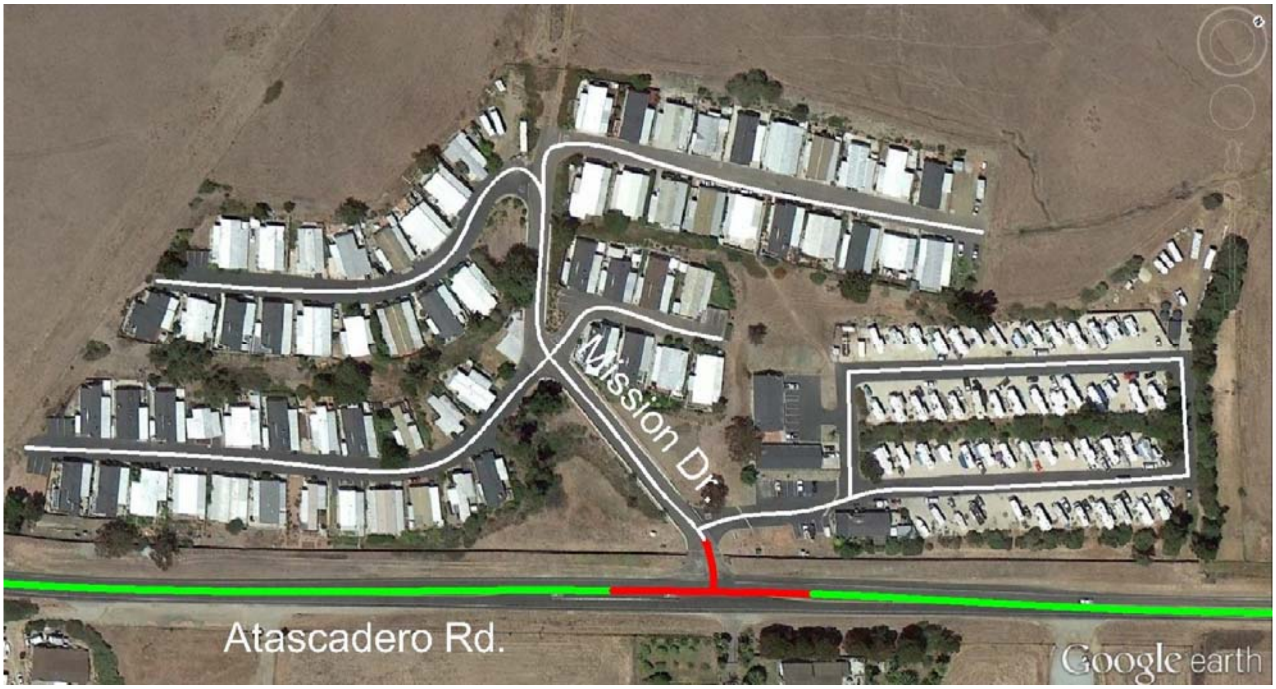
Oakhurst: Meadowview Drive and Road 426

***Oakhurst, Meadowview Drive and Road 426, Madera County** – A single-access subdivision with a few short branches from the primary spine road (Meadowview Drive).*

Foothill Boulevard and O'Connor Way – Mixed Use

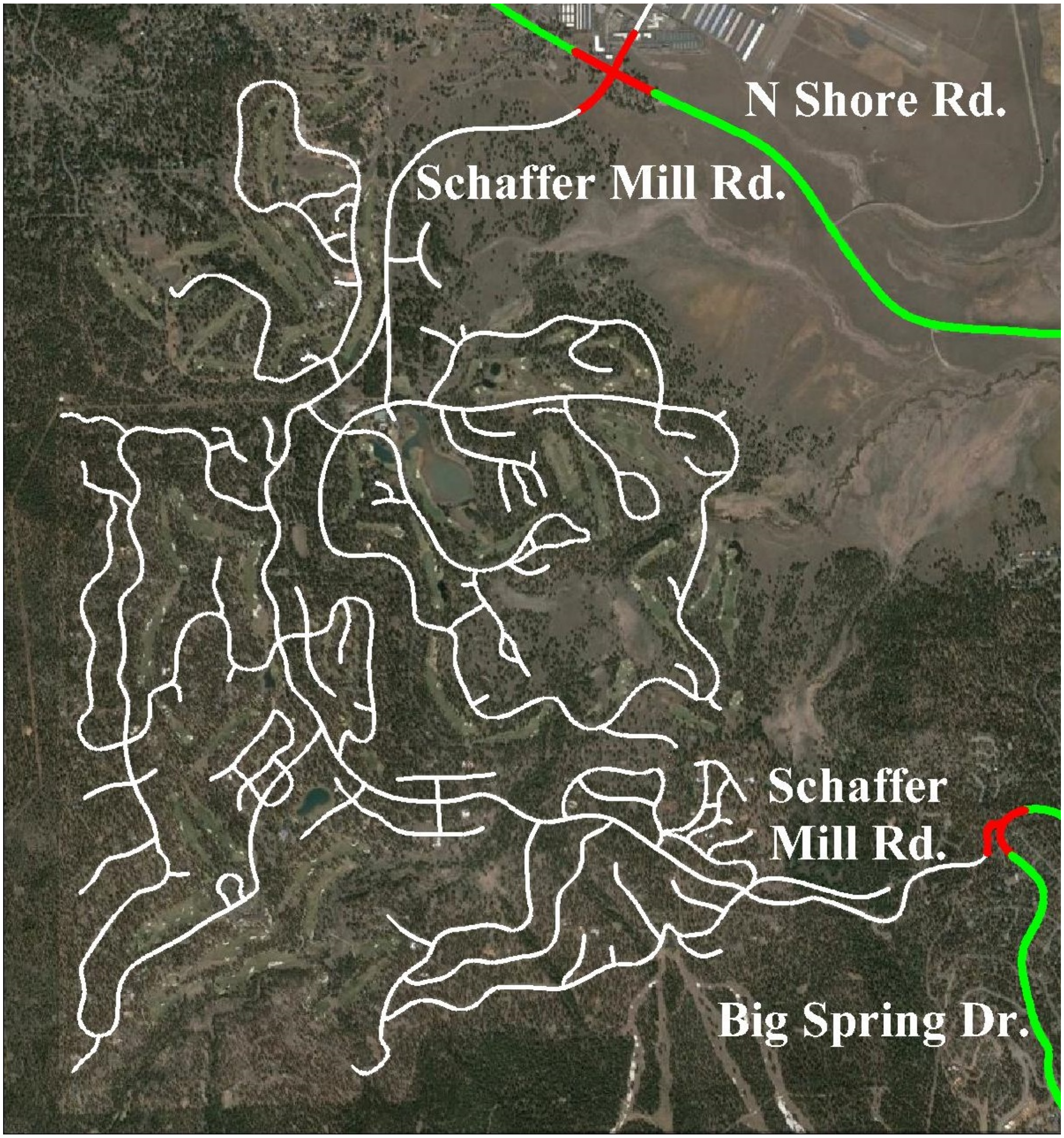
***Foothill Boulevard and O'Connor Way, San Luis Obispo County** – A mixed-use single-access subdivision with several short branches from the primary spine road (O'Connor Way). Land uses include homes, schools, and churches: The Agape Church with a congregation of 400 to 440 people, Temple Ner Shalom with of congregation of 200 people, and the Laureate School with a population of 120.*

Atascadero Road and Mission Drive – Mobile Home Park



Atascadero Road and Mission Drive, Morro Bay, San Luis Obispo County *– A tightly packed mobile home park with a single access via Mission Drive. The largest parcel size is 110 feet by 90 feet, and the smallest parcel size is 45 feet by 60 feet.*

Northwest Lake Tahoe

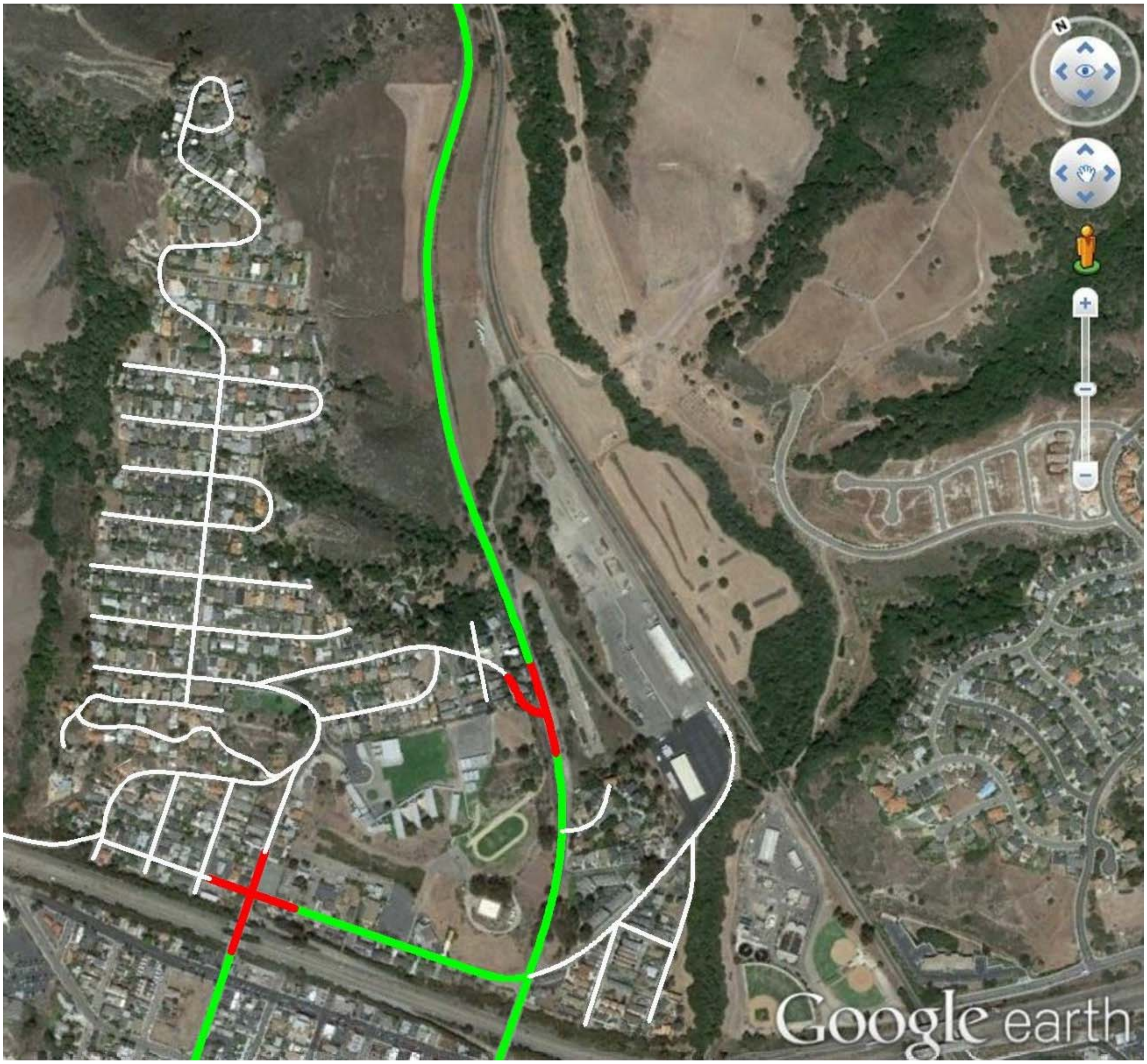


Northwest Lake Tahoe, Truckee, Placer County *– A development in the Northstar area, with secondary access enabling so much land use that the two exits become major bottlenecks with very long evacuation times.*

Norris Canyon Estates

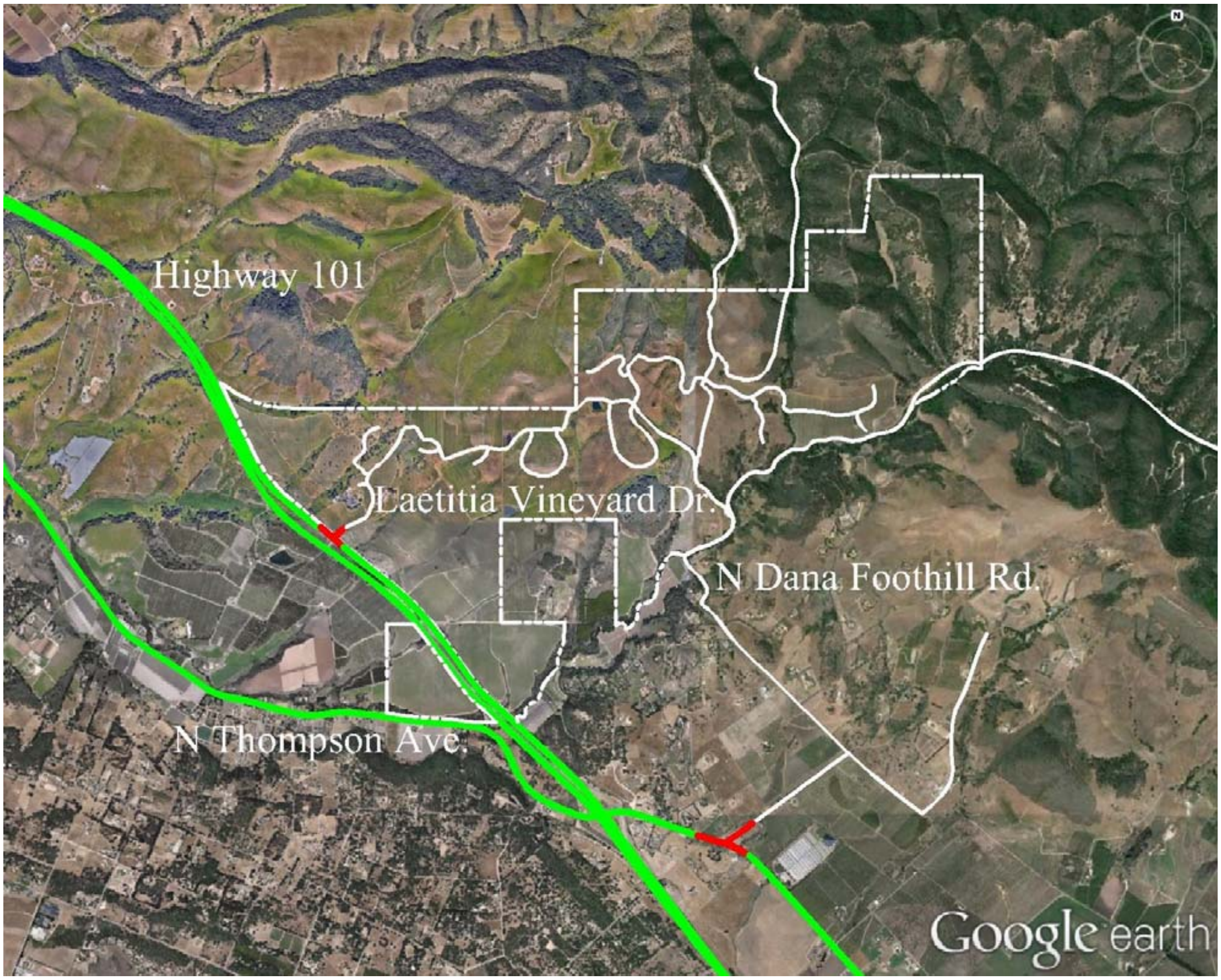
***Norris Canyon Estates, San Ramon, Contra Costa County** – A single-access subdivision with several branches from the primary spine road (Ashborne Drive). While the subdivision appears to have two access points, they are close enough to each other that they will effectively function as one exit during emergency evacuation.*

Pismo Heights



Pismo Heights, Pismo Beach, San Luis Obispo County *– A highly stacked single-access subdivision with several branches from the primary spine road (Longview Avenue), with two access points that are both toward one end of the development, restricting the evacuation path for most residents in the upper portion of Longview Avenue.*

Highway 101 and Laetitia Vineyard Drive – Proposed Development



***Highway 101 and Laetitia Vineyard Drive, Nipomo, San Luis Obispo County** – A proposed subdivision with several branches from the primary spine road. The subdivision has two exits at opposite ends of the development, but the secondary access (Laetitia Vineyard Drive) connects to the heavily traveled, high-speed Highway 101, creating a very dangerous situation when used. The proposed subdivision is in reality a single-access development.*

Mission Canyon

Mission Canyon, Santa Barbara, Santa Barbara County *– A stacked single-access development in hilly terrain with residences that are not reachable by large emergency vehicles.*

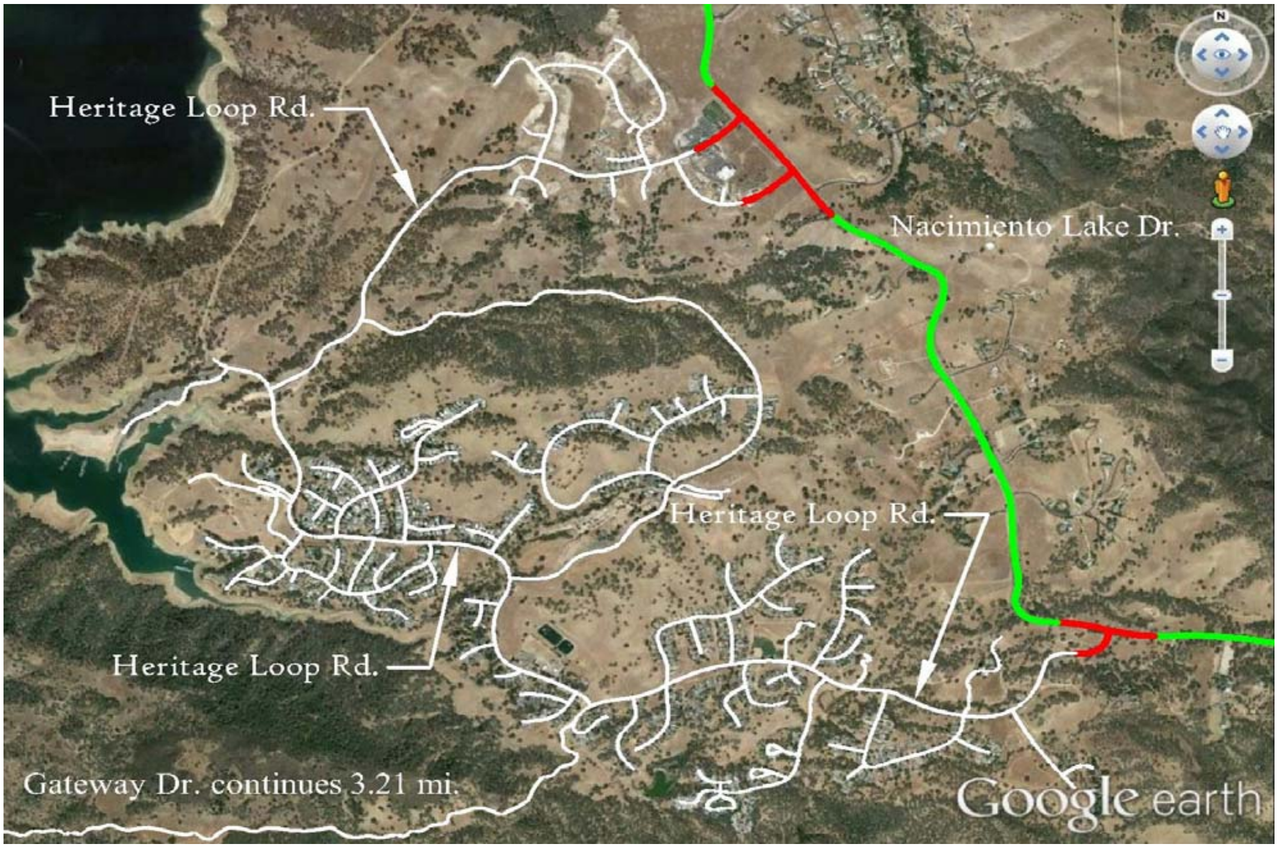
Winchester Canyon

Winchester Canyon, Goleta, Santa Barbara County *– A single-access development with most subdivision roads connecting by a single access to the primary single-access spine (Winchester Canyon Road).*

Santa Barbara Riviera

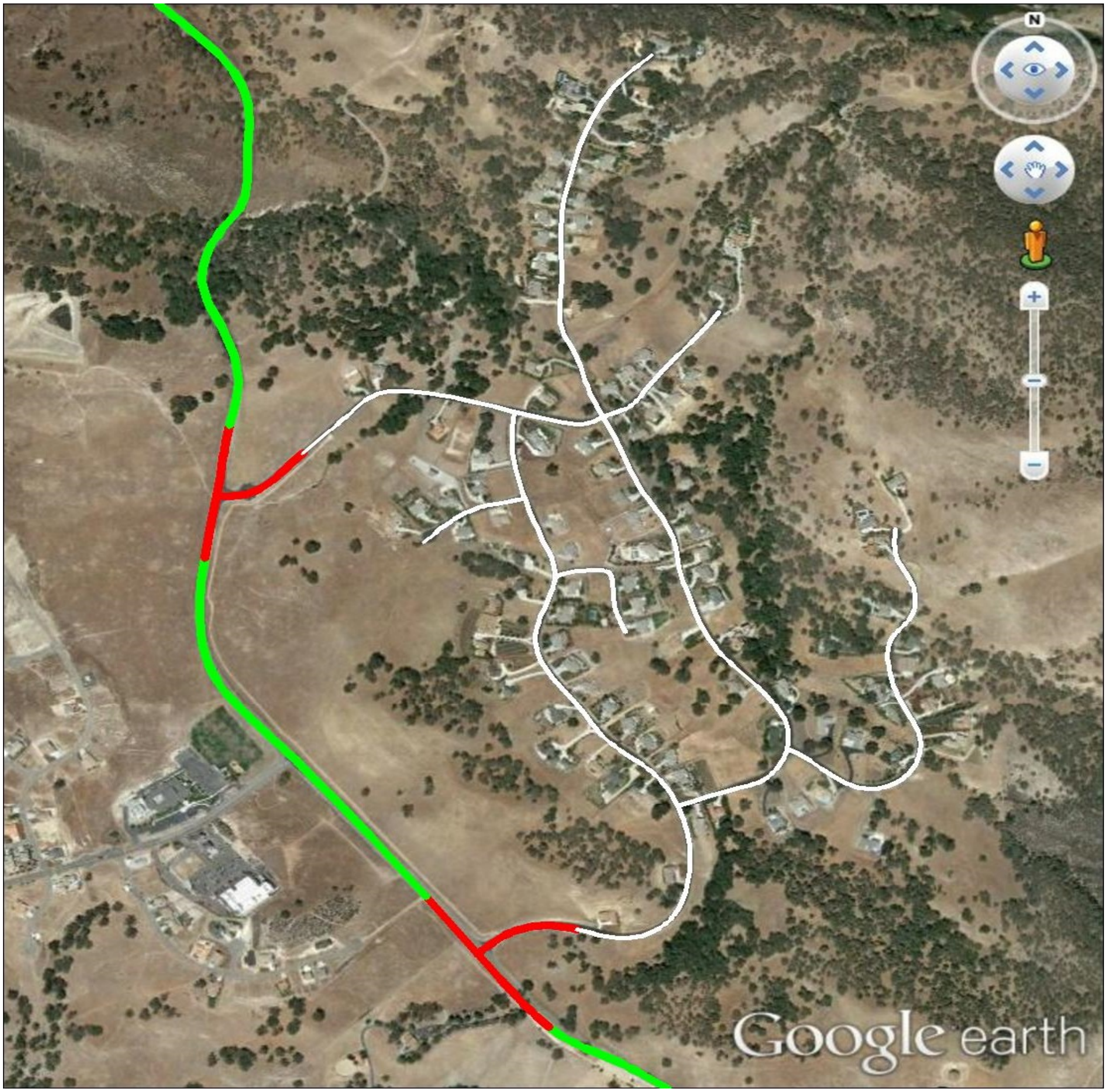
Santa Barbara Riviera, Santa Barbara, Santa Barbara County *– A development in hilly terrain, with multiple entrances that open onto the same surrounding arterial streets, effectively turning escape routes into potential problem routes during emergency evacuation.*

Heritage Ranch



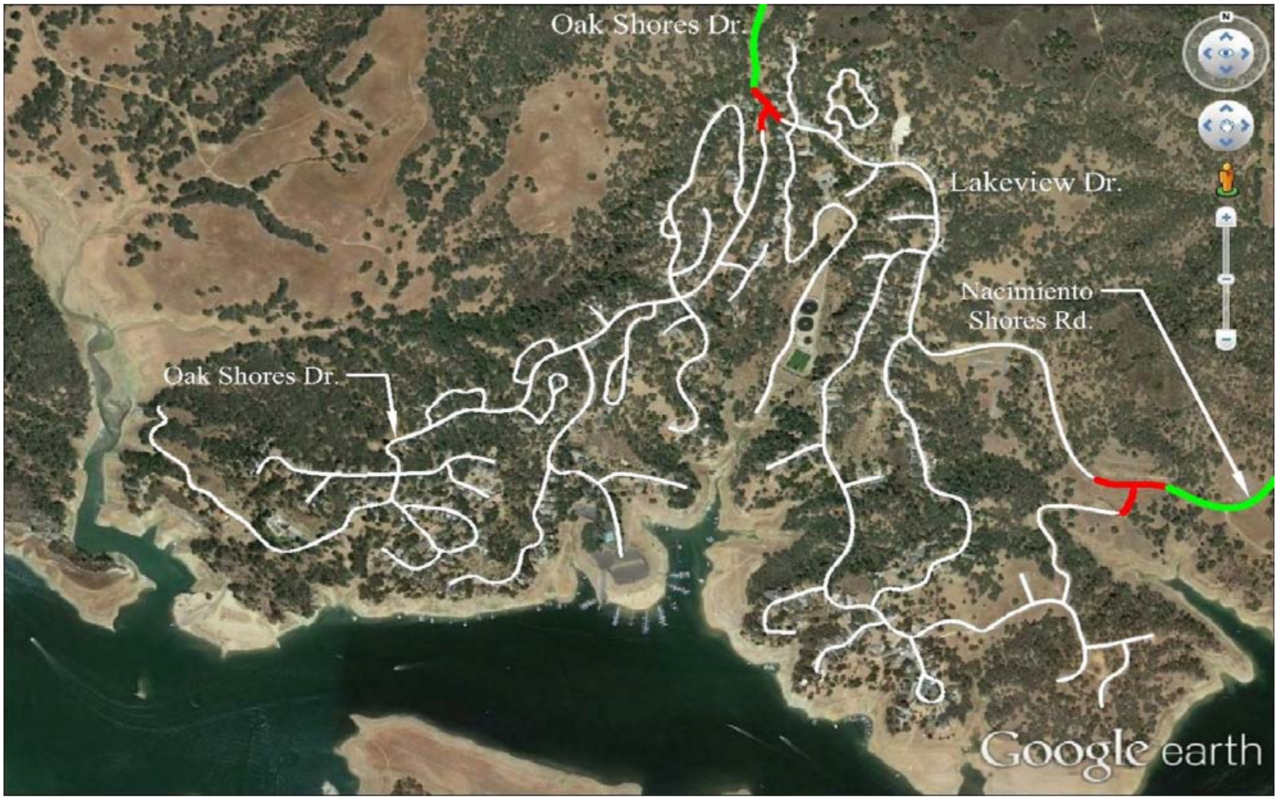
***Heritage Ranch, Paso Robles, San Luis Obispo County** – A development with secondary access serving so many parcels that the two exits become major bottlenecks with very long evacuation times.*

River Oaks



River Oaks, Lake Nacimiento, San Luis Obispo County *– A development with secondary access but a limited number of homes, enabling the two exits to work during evacuation.*

Oak Shores



Oak Shores, Lake Nacimiento, San Luis Obispo County *– A development with secondary access serving so many parcels that the two exits become major bottlenecks with very long evacuation times.*

Results of Applying the Tool to Case Studies

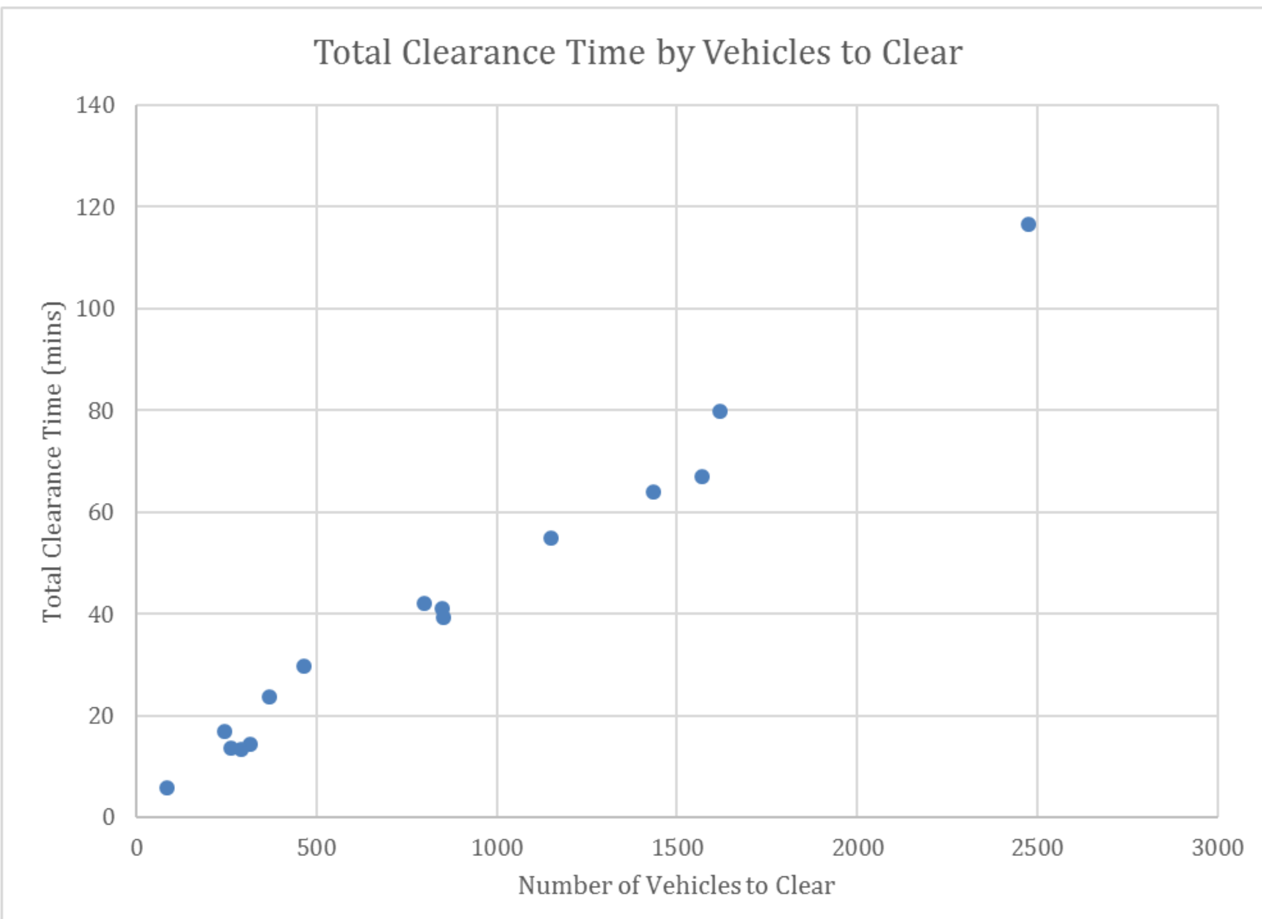
General Observations

Table 3-1, which was previously presented, shows a summary of the results for each case study. Examination of case study results led to certain general observations that may be outlined as follows:

1. In 8 of the 14 cases, evacuation was estimated to take more than 30 minutes. This is quite a long time threshold, considering that recent wild fires took much less time than that to burn through major portions of communities.
2. In 13 of the 14 cases, evacuation was estimated to take more than 10 minutes to clear.
3. As expected, there was a strong, positive association between the size of development and the time to clear, even in cases that have secondary access. In other words, evacuation was estimated to take longer in larger developments. Figure 3-9 illustrates the association.

The next subsection includes deliberate comparisons of varying situations. Each comparison leads to a preliminary conclusion.

Figure 3-9: Total Clearance Time by Size of Development (Number of Vehicles to Clear)



Comparisons of Varying Situations Reflected in Case Studies

Single vs. Mixed Use – Foothill Boulevard at O'Connor Way, San Luis Obispo County

This subdivision has almost 50 homes, which equated to persons in 105 passenger cars that were estimated to be cleared within 10 minutes; this scenario assumes that the school, church, and synagogue were not in operation at the time of the incident. Assuming all the uses are operational during emergency evacuation, persons in approximately 466 vehicles would need to be evacuated over an estimated period of nearly 30 minutes. In other words, mixed use would require three times more clearance time than residential single use. Table 3-2 shows comparative results that led to the following conclusion:

The type and intensity of land use in single-access subdivisions should not be ignored.

Table 3-2: Single vs. Mixed Use Clearance Times

	Normal Travel Time of Farthest Vehicle (seconds)	Delay to Farthest Vehicle (seconds)	Total Travel Time for Farthest Vehicle Time (seconds)	Number of Vehicles to Clear	Average Network/Facility Operating Speed (mph)	Total Clearance Time (minutes)
Single Land Use (residential)	305	0	305	105		**9.5**
Mixed Land Use (homes, school, church, and synagogue)	367	248	615	466	**8.4**	**29.7**

Single vs. Multiple Entrances – Heritage Ranch, Paso Robles, San Luis Obispo County

This subdivision is vast, with two widely separated access points on the same through road. In applying the tool, it was assumed that residents would be directed to the nearest exit based on ***distance to the nearest exit.*** The application produced highly varied clearance times: 64 minutes for the western entrance (which would serve fewer vehicles) and 117 minutes for the eastern entrance (which would serve many more vehicles). Even if, with constant communications, residents were able to switch routes to balance exit times, the average clearance time for each exit would be approximately 90 minutes. The results of this application led to the following conclusion:

Simply providing two entrances for a development of uncontrolled size may not be sufficient to ensure safe evacuation of occupants in the event of an emergency.

Potential Effects of Fire – Smoke Limiting Visibility in Northwest Lake Tahoe, Truckee, Placer County

This comparison used studies of fog as a surrogate for the thick smoke that may arise during a wildland fire. The studies suggest increases of 10% to 50% in travel time when visibility is limited.[13] Assuming a 50% increase in travel time due to thick smoke, the clearance time for the Northwest Lake Tahoe development would worsen from 80 minutes on a normal severe fire weather day to 92 minutes. This equates to a 24% reduction in network travel speed (from 7.6 mph to 5.8 mph) and a 15% increase in clearance time. Table 3-3 shows comparative results that led to the following conclusion:

Potential effects of fire on visibility can add significantly to clearance times.

Table 3-3: Potential Effects of Fire on Clearance Times

	Normal Travel Time of Farthest Vehicle (seconds)	Delay to Farthest Vehicle (seconds)	Total Travel Time for Farthest Vehicle Time (seconds)	Number of Vehicles to Clear	Average Network/Facility Operating Speed (mph)	Total Clearance Time (minutes)
Normally severe fire weather day	730	8	738	1621	**7.6**	**79.9**
Smoke-engulfed day	1459	17	1476	1621	**5.8**	**92.2**

Potential Effects of Delay at Through Road Intersection – Pismo Heights, Pismo Beach, San Luis Obispo County

Pismo Heights is a single-access subdivision along Longview Avenue in Pismo Beach. Longview Avenue ends at its intersection with Wadsworth Street. Just below that intersection, residents have two route choices for exit:

- East on Lemoore Avenue to Price Canyon Road
- South on Wadsworth Street with three choices at Bello Street:
  - Left on Bello Street to Price Canyon Road
  - Right on Bello Street to the Highway 101 northbound on-ramp at Bay Street
  - Straight on Wadsworth Street toward the beach

[13] Federal Highway Administration website: http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

Using existing intersection analysis for Bello Street at Price Canyon Road as a surrogate for constrained delay at a main through road intersection led to the following findings:

- Vehicles on the eastbound approach are estimated to experience about 15 seconds of delay during AM and PM peak periods. Each vehicle ahead of the last vehicle to exit the development would experience that level of delay.
- If all 1,149 vehicles to exit the development were equally divided among the four available route choices, 287 vehicles would have to navigate the Bello Street intersection. The time required would be 4,310 seconds, or 72 minutes.
- Total clearance time would increase by more than an hour, from 55 minutes to 127 minutes, due to delay at the main arterial intersection. Anecdotal information confirms that it takes this long to exit the development on such holidays as the Fourth of July, when many people are leaving the subdivision after watching the fireworks on the pier.

Table 3-4 shows comparative results that led to the following conclusion:

Potential effects of perennial delays at a primary through road intersection can add significantly to clearance times.

Table 3-4: Potential Effects of Delay at Main Through Road Intersection

	Normal Travel Time of Farthest Vehicle (seconds)	Delay to Farthest Vehicle (seconds)	Total Travel Time for Farthest Vehicle Time (seconds)	Number of Vehicles to Clear	Average Network/Facility Operating Speed (mph)	Total Clearance Time (minutes)
Excluding delay at through road intersection	217	200	417	1,149	**6**	**55**
Including delay at through road intersection						**127**

Reassessment of Existing Standards

Findings from the case studies confirm initial assessments of the existing standards from earlier testing of hypothetical situations, which were crafted to conform to the parcel-size and distance specifications of the law. Table 3-5 shows similar patterns of results with application of the tool to hypothetical cases, as compared to the initial, quick analyses of hypothetical situations.

Table 3-5: Potential Effects of Delay at Main Through Road Intersection on Hypothetical Cases

	Normal Travel Time of Farthest Vehicle (seconds)	**Delay to Farthest Vehicle (seconds)**	**Total Travel Time for Farthest Vehicle (seconds)**	**Number of Vehicles to Clear**	**Average Network/Facility Operating Speed (mph)**	**Total Clearance Time -- No Delay at Through Road Intersection (minutes)**	**Total Clearance Time -- With Delay at Through Road Intersection (minutes)[1]**
Various parcel sizes – without mitigation options							
< 1acre; 120 DU	22	47	68	293	7	13	87
1 to 4.99 acres; 44 DU	36	10	46	112	14	6	34
5 to 19.99 acres; 34 DU	72	23	95	83	20	5	26
20 acres +; 36 DU	144	47	191	88	22	7	29
Parcels zoned for less than 1 acre – with potential mitigation options							
240 dwelling units (DU)	22	93	115	587	4	26	173
120 DU; 1 exit lane	22	47	68	293	7	13	87
120 DU; 2 exit lanes	22	23	45	293	9	13	86
120 DU; 1 lane; 2 exits	22	47	68	147	8	7	44
120 DU + school; 1 lane	22	127	148	538	5	25	159
120 DU + school; 2 lanes	22	63	85	538	7	24	158
120 DU + school; 2 exits	22	130	152	269	5	14	81

[1] *Assumes an average of 15 seconds of delay per vehicle accumulated from first exiting to last exiting vehicle.*

Summary of Preliminary Conclusions from Case Studies

In summary, the case studies led to the following preliminary conclusions:

1. The type and intensity of land use in single-access subdivisions should not be ignored.
2. Simply providing two entrances for a development of uncontrolled size may not be sufficient to ensure safe evacuation of occupants in the event of an emergency.
3. Potential effects of fire on visibility can add significantly to clearance times.
4. Potential effects of perennial delays at a primary through road intersection can add significantly to clearance times
5. Simply adding an additional lane to the primary single access road for evacuation does not appear to improve evacuation times. Adding a true second access that is independent of the first (meaning the two exits are neither close together nor access the same through road) offers a significant reduction in clearance time. In developments with high intensities of land use, however, clearance time can remain high. Under these conditions, multiple entrances (not just one or two) could offer the highest potential for timely evacuation.

This page intentionally left blank

4.0 Fire Behavior Modeling

Overview

The inputs used by CAL FIRE in the calculations that lead to designation of Fire Hazard Severity Zones (FHSZs) have been codified into California law and are accepted as being based on sound science. For these reasons, the team initially hoped to model potential fire behavior (i.e., flame length and rate of spread) using these same inputs. FHSZs are categorized as Moderate, High, or Very High and are designated based upon multiple characteristics for a given area, including:

1. Potential vegetation type, structure, and moisture
2. Topographic slope
3. Likelihood of a fire transitioning from a surface fire to a crown fire
4. Firebrand generation
5. Probability of burning (based on historical fire frequency of an area)

Unfortunately, it was not possible simply to use the specific inputs used to categorize FHSZs for a given site, because the inputs are not publicly available. Further, the FHSZ designation for a given area could not be used as a surrogate for fire behavior, because these designations incorporate an element of probability of the area burning, which varies from place to place even if all else is equal; thus, two areas could be identical in vegetation and slope but could differ in FHSZ designation due to differing probabilities of burning, which are based on the historical fire frequency of the area. For the purpose of the study, probability was not relevant, since the concern was safe ingress and egress **given the occurrence of a fire**, irrespective of the likelihood that it would occur.

While the team was precluded from using the specific fire behavior calculations used in designating FHSZs, an attempt was made to use those same general principles and methodologies to estimate relative fire rates of spread and intensity. For example, NEXUS software (Scott & Burgan 2001) was used to calculate fire intensity and spread. Further, fuel moisture inputs were also used, based upon a "normally severe fire weather day," a common precept in FHSZ calculations. Other inputs used here were based on the team's personal experience in fire behavior modeling, the scientific literature, and consultation with CAL FIRE fire scientists at the Fire and Resource Assessment Program.

Modeling Inputs

Flame length and spread rate were modeled for the following four general vegetation classes:

- Grass (see examples in Figure 4-1)
- Shrubs (see examples in Figure 4-2)
- Coniferous forest (see examples in Figure 4-3)
- Broadleaf forest (see examples in Figure 4-4)

While these vegetation classes do not come close to simulating the vast array of fine-scale variability found from site to site in California, they provide general types that would be easily understood by non-practitioners.

Figure 4-1: Examples of Grass Vegetation Class

Grass vegetation class: *Potential examples include grasslands, oak savannahs, meadows, and others. Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory (http://www.fs.fed.us/pnw/fera/publications/photo_series_pubs.shtml).*

Figure 4-2: Examples of Shrub Vegetation Class

***Shrub vegetation class**: Potential examples include chaparral, coastal sage scrub, Great Basin sagebrush, and others.*

Figure 4-3: Examples of Coniferous Vegetation Class

***Coniferous vegetation class**: Potential examples include mixed conifers, ponderosa pine, redwood, Douglas fir, and others.*

Figure 4-4: Examples of Broadleaf Vegetation Class

***Broadleaf vegetation class**: Potential examples include closed canopy oak, madrone, tanoak, and bay laurel.*

As previously noted, fire behavior simulations were intended to approximate a "normally severe fire weather day," a precept in FHSZ calculations. To that end, all vegetation/slope combinations were calculated over a range of wind speeds from 0 to 60 mph, enabling users to determine which wind speed is of most realistic concern for their local area. Further, as in FHSZ calculations, fuel moistures were calculated under a "very low dead, fully cured herb" moisture scenario, which is a common term used in fire behavior modeling.

Also as in FHSZ calculations, topography (slope) was categorized into six basic classes, which are based on National Fire Danger Rating System categories. Median values for the following classes were used in fire behavior calculations:

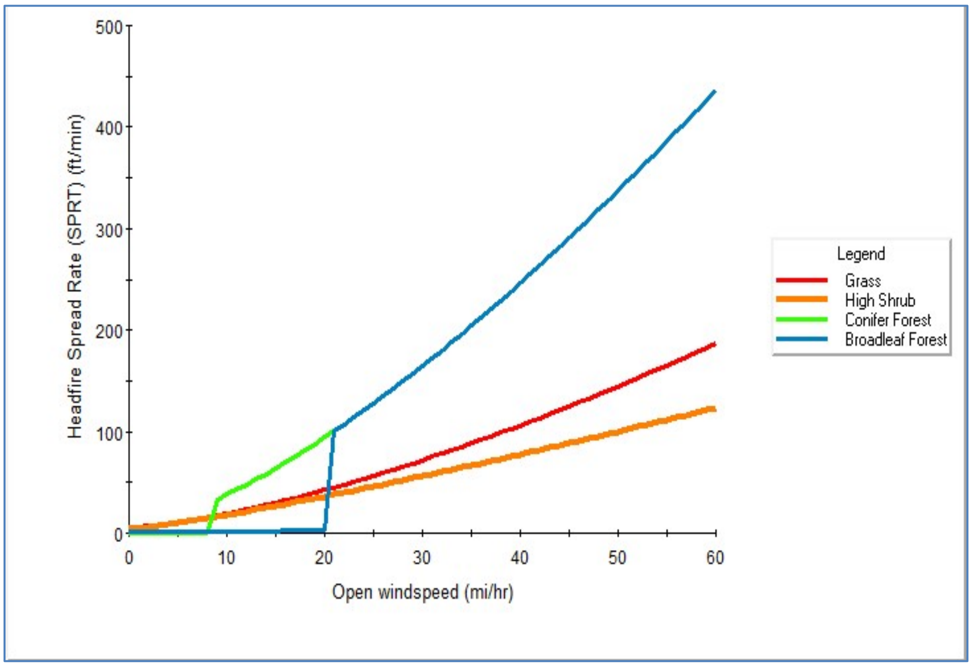
- 0%
- 1-25%
- 26-40%
- 41-55%
- 56-75%
- >85%

Details regarding the specific fuel, weather, and topography inputs used for fire behavior simulations are provided in Appendix 3. Note that, due to differences in vegetative structure, vegetation classes do not all require the same types of inputs. (For example, grass has no tree canopy properties, and thus these inputs are precluded in the fire behavior calculations for that vegetation class.)

Modeling Outputs

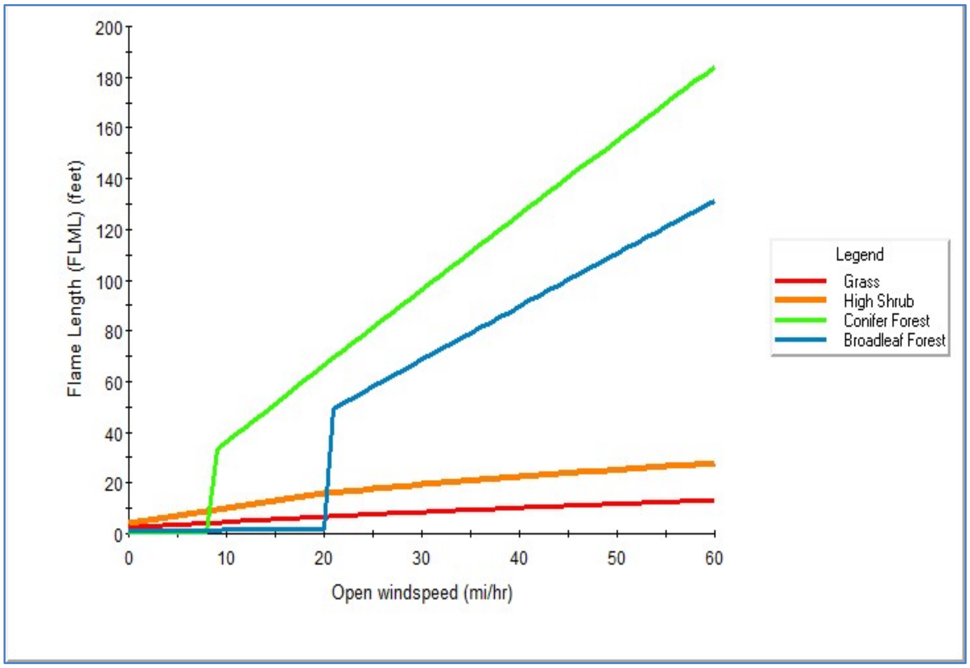
Figures 4-5 and 4-6 illustrate simulated rates of fire spread and flame length, respectively, over a range of wind speeds. In general, spread rate and flame length were greatest for shrubs, then grass, and then forests until wind exceeded a threshold speed and fires in the forest types transitioned from a low-intensity surface fire into a high-intensity crown fire. These trends, while generalized for a given vegetation class, are considered realistic.

Figure 4-5: Fire Spread Rate for Vegetation Classes –
"Normally Severe Fire Weather Day" Scenario



*Fire **spread rate** (in feet per minute) for four vegetation classes under a "normally severe fire weather day" scenario.*

Figure 4-6: Fire Flame Length for Vegetation Classes –
"Normally Severe Fire Weather Day" Scenario



*Fire **flame length** (in feet) for four vegetation classes under a "normally severe fire weather day" scenario.*

Figures for fire spread rate and fire flame length for *mitigated* vegetation can be found in Appendix 3.

Based on these simulation outputs, look-up tables of fire behavior (i.e., spread rate and flame length) were created for each of the vegetation classes under multiple defined combinations of wind speed and slope. An example look up table (for grass vegetation) is provided in Table 4-1; others can be found in Appendix 3.

Table 4-1: Look-Up Table of Fire Behavior for Grass Vegetation Class under Varying Combinations of Slope and Wind Speed

Vegetation: Grass						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 6'/min FL: 3'	ROS: 19'/min FL: 5'	ROS: 42'/min FL: 7'	ROS: 71'/min FL: 9'	ROS: 106'/min FL: 10'	ROS: 144'/min FL: 12'
1-25	ROS: 9'/min FL: 3'	ROS: 23'/min FL: 5'	ROS: 46'/min FL: 7'	ROS: 75'/min FL: 9'	ROS: 110'/min FL: 10'	ROS: 148'/min FL: 12'
26-40	ROS: 29'/min FL: 6'	ROS: 42'/min FL: 7'	ROS: 65'/min FL: 8'	ROS: 95'/min FL: 10'	ROS: 129'/min FL: 11'	ROS: 168'/min FL: 13'
41-55	ROS: 55'/min FL: 8'	ROS: 69'/min FL: 8'	ROS: 91'/min FL: 10'	ROS: 121'/min FL: 11'	ROS: 155'/min FL: 12'	ROS: 194'/min FL: 14'
56-75	ROS: 96'/min FL: 10'	ROS: 109'/min FL: 10'	ROS: 132'/min FL: 11'	ROS: 162'/min FL: 12'	ROS: 196'/min FL: 14'	ROS: 234'/min FL: 15'
>75	ROS: 159'/min FL: 12'	ROS: 173'/min FL: 13'	ROS: 196'/min FL: 14'	ROS: 225'/min FL: 14'	ROS: 260'/min FL: 15'	ROS: 298'/min FL: 16'

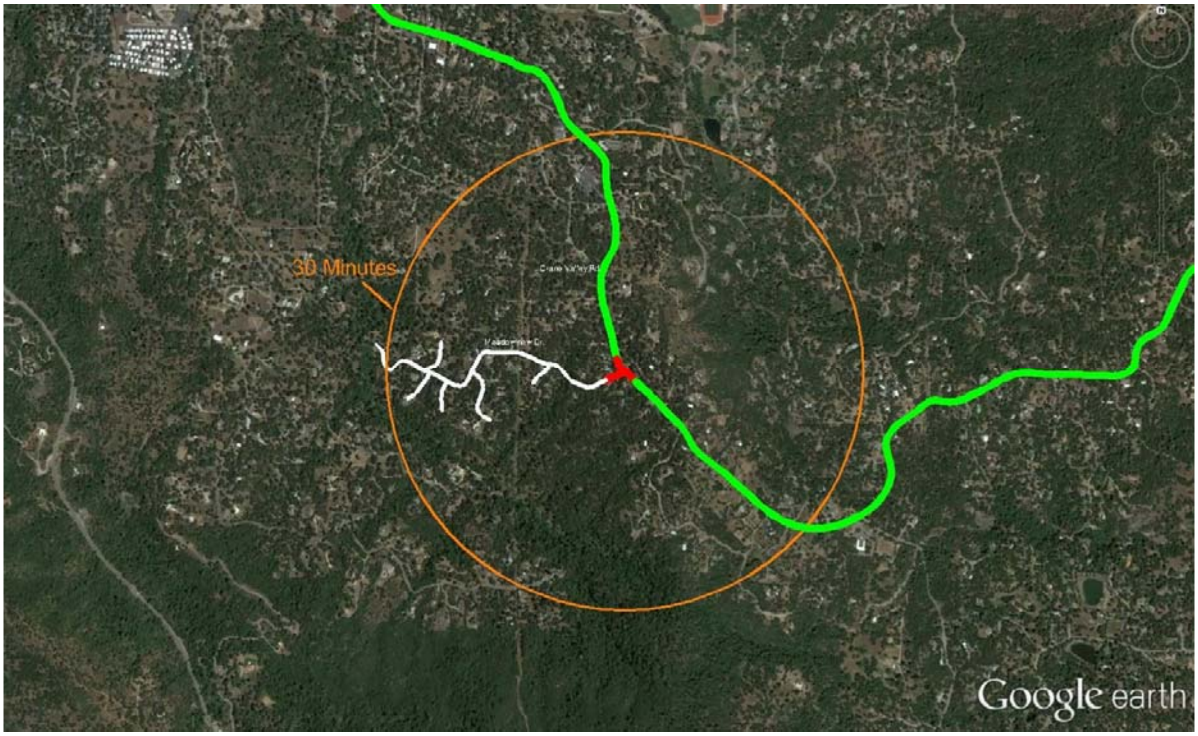
ROS = rate of spread; FL = flame length.

Conclusions Regarding Fire Behavior Modeling

Unfortunately, direct linkage with the access model is presently precluded. Fire behavior calculations here are instead intended to provide planners with a valuable source of information to inform their decision making. That said, one could potentially reverse-engineer a fire's area of influence from a given point (e.g., the exit point of a single-access subdivision) based upon potential fire rate of spread and a specific time of interest. For example, the transportation model might predict that 30 minutes are required to fully evacuate a given subdivision.

Given the predicted fire rate of spread (See look up tables in Appendix 3), a planner could then determine the relative boundaries of a fire's influence from that given point (see Figure 4-7). In this hypothetical scenario, a fire could reach the access point from any point within the 30-minute boundary, dependent on direction of spread and other factors.

Figure 4-7: Conceptual Area of Fire Influence within 30 Minutes of Access Point



*Conceptual area of **fire influence within 30 minutes** of the access point for Oakhurst subdivision.*

Users should be cautioned that the fire behavior values here are to be used as a general guide and not as a sound predictor of site-specific fire behavior. The latter would require an expert in fire prediction systems or a future spatial tool that gives users easy access to the fire behavior predictions used in the FHSZ designation of a given area. For example, as previously noted, vegetation was divided into just four classes, an approach that provides for easy understanding but does not account for the enormous fine-scale variability found throughout California. Further, calculations here do not include any mitigation measures (e.g., fuel treatments) that might modify fire behavior; as in FHSZ calculations, the calculations presented here are intended to illustrate realistic fire behavior in mature vegetation on a "normally severe fire weather day." Also, spread rate here does not consider spotting from embers, which can exponentially increase the spread of a fire, especially as it transitions from a surface fire into a crown fire.

Finally, the team believes that future endeavors could improve predictions of both egress and fire behavior by creating a tool that would enable a user to easily obtain the same site-specific fire behavior calculations used in FHSZ designation. The function of this tool would be maximized by seamlessly linking the access model with fire behavior predictions.

5.0 Illustrations: Linking Access With Fire Behavior

Introduction

This section contains illustrations (utilizing actual case study sites) of the manner in which information from the fire behavior modeling might be used to assist planners in better understanding wildfire spread in various situations and relating this to estimates of clearance times, **subject to the caveats expressed in Section 4.0.** There are four illustrations from the Oakhurst case study and seven from the Heritage Ranch case studies. The analyses are based on prevailing as well as more extreme conditions (e.g., wind speed) at each site.

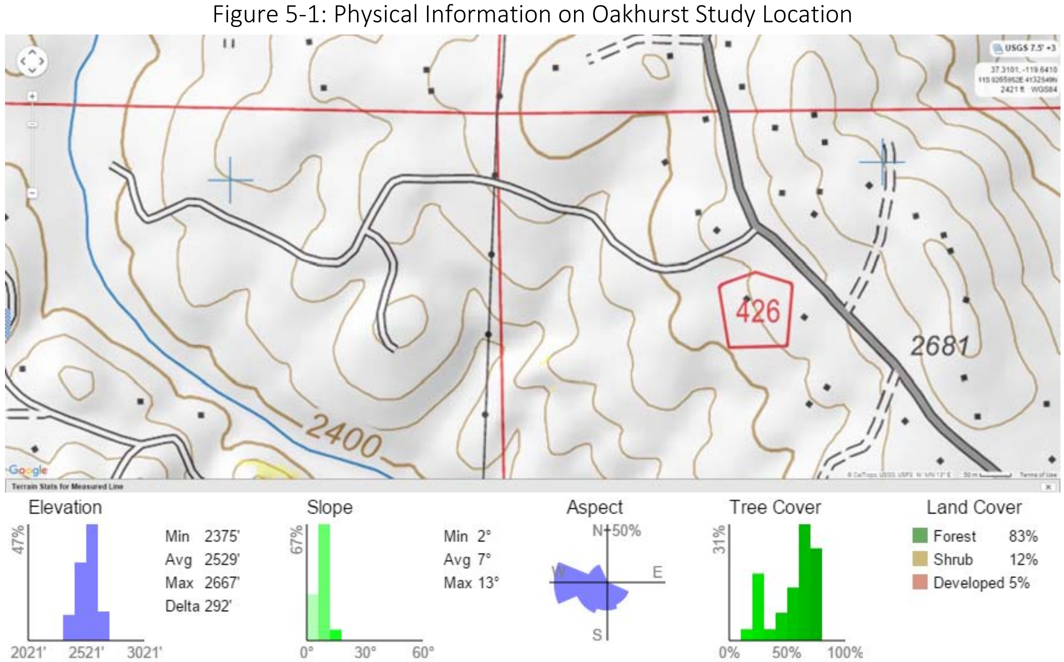
Case Study: Oakhurst – 1

Conditions

Figure 5-1 shows existing physical conditions in the vicinity of the Oakhurst case study site. In summary, conditions depict the following:

Vegetation: Broadleaf Forest (existing)
Slope: 1% to 25% (existing)
Wind speed: 30 mph (assumed for a "normally severe fire weather day")

Figure 5-1: Physical Information on Oakhurst Study Location



Source: Cal Topo using resources from Google Maps; USGS, and USFS

Associated Look-Up Table

Table 5-1 shows the appropriate look-up table for the case study site. It also shows the appropriate cell of fire behavior model parameters to use.

Table 5-1: Look-Up Table Applied to Oakhurst Study Location

Vegetation: Broadleaf Forest (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 1'/min FL: 1'	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 165'/min FL: 69'	ROS: 246'/min FL: 90'	ROS: 337'/min FL: 111'
1-25	ROS: 1'/min FL: 1'	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 166'/min FL: 69'	ROS: 248'/min FL: 90'	ROS: 338'/min FL: 111'
26-40	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 103'/min FL: 50'	ROS: 174'/min FL: 71'	ROS: 255'/min FL: 92'	ROS: 346'/min FL: 112'
41-55	ROS: 4'/min FL: 2'	ROS: 5'/min FL: 3'	ROS: 114'/min FL: 54'	ROS: 184'/min FL: 74'	ROS: 266'/min FL: 94'	ROS: 356'/min FL: 115'
56-75	ROS: 7'/min FL: 3'	ROS: 8'/min FL: 3'	ROS: 130'/min FL: 58'	ROS: 200'/min FL: 78'	ROS: 282'/min FL: 98'	ROS: 372'/min FL: 118'
>75	ROS: 45'/min FL: 19'	ROS: 98'/min FL: 48'	ROS: 155'/min FL: 66'	ROS: 225'/min FL: 84'	ROS: 307'/min FL: 104'	ROS: 398'/min FL: 123'

Model Parameters

For the given slope range of 1% to 25% and assumed wind speed of 30 mph, the look-up table indicates the following parameters:

Rate of spread = 166 feet per minute (1.9 mph)
Flame length = 69 feet
Start of fire = 500 feet west of development (assumed)

Potential Spread of Fire by Time Period

For an assumed location of fire at a hypothetical distance of 500 feet west of the development, Figure 5-2 shows how long it would take for the fire to engulf specified sections of the development in 5 minute increments assuming there were no intervention from fire professionals. Results indicate that the fire would reach points farthest west of the development In approximately 3 minutes, engulf nearly half of the development within 15 minutes, and overrun the entire development within 20 minutes.

Figure 5-2: Potential Spread of Fire at 30-mph Wind Speed from 500 Feet West of Oakhurst

Parameters

For given slope of 1% to 25%, assumed wind speed of 30 mph, and start of fire at 500 feet west of development:

- Rate of spread = 166 feet per minute (1.9 mph)
- Flame length =69 feet

Table 5-2 shows how these results compare with the estimated total clearance time for this development, which 6 minutes if no further delay at the exit intersection is assumed. If prevailing or projected conditions at the through road intersection (for instance from a traffic impact study) indicate that delay per vehicle is 10 seconds at the bottleneck, clearance time would more than triple to 20 minutes, threatening all residents of the subdivision, but especially those furthest west in the development. Note that this clearance time would be possible only if evacuation began immediately after the fire started. Every increase in time-lapse between start of fire and time of an evacuation order would make it less likely that all vehicles would exit the subdivision under this wind speed scenario.

Table 5-2: Oakhurst with Potential Effects of Delay at Main Through Road Intersection

Oakhurst: *Level of Delay Assumed per Vehicle at Through Road Intersection (seconds)*	**Normal Travel Time of Farthest Vehicle (seconds)**	**Delay to Farthest Vehicle (seconds)**	**Total Travel Time for Farthest Vehicle (seconds)**	**Number of Vehicles to Clear**	**Average Network /Facility Operating Speed (mph)**	**Total Clearance Time -- No Delay at Through Road Intersection (minutes)**	**Total Clearance Time -- With Delay at Through Road Intersection (minutes)**
0	105	33	138	86	12	6	6
5							13
10							20
15							27
20							34

Case Study: Oakhurst – 2

Assuming the wind speed were 20 mph, the fire model parameters indicate a much reduced rate of spread of 3 feet per minute. Figure 5-3 indicates that the fire would reach the development in a little under 3 hours and engulf the entire subdivision in approximately 18 hours. This is close to a best case scenario. Compared to estimates from the access tool in Table 5-2, a prevailing delay of 20 seconds per vehicle at the through road intersection would result in a clearance time of 34 minutes, which is well under the time needed to clear all residents before the fire reaches the farthest west part of the subdivision assuming no intervention.

Figure 5-3: Potential Spread of Fire at 20-mph Wind Speed from 500 Feet West of Oakhurst

Parameters

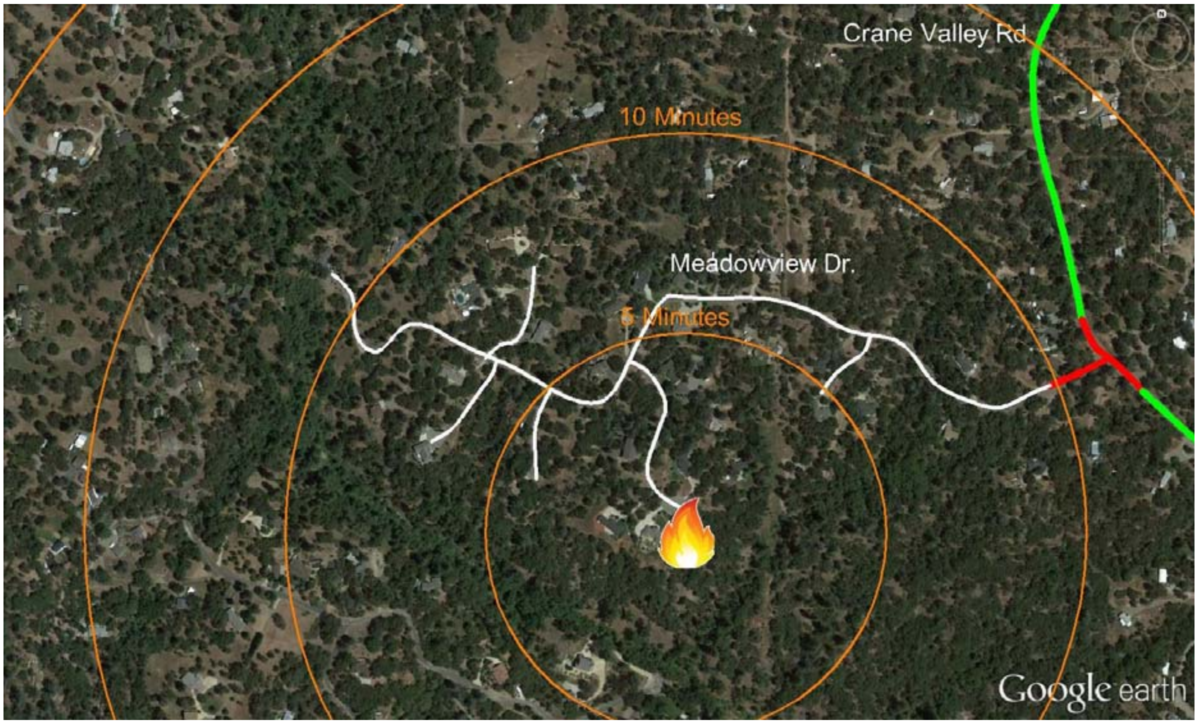
For given slope of 1% to 25%, assumed wind speed of 20 mph, and start of fire at 500 feet west of development:

- Rate of spread = 3 feet per minute (0.034 mph)
- Flame length = 2 feet

Case Study: Oakhurst – 3

Figure 5-4 depicts another hypothetical situation that assumed the fire begins close to the outskirts of the development, 100 feet to the south. Given the proximity of the fire, the entire development would be threatened sooner than the first case. The fire could potentially engulf the subdivision within 10 minutes.

Figure 5--4: Potential Spread of Fire at 30-mph Wind Speed from 100 Feet South of Oakhurst



Parameters

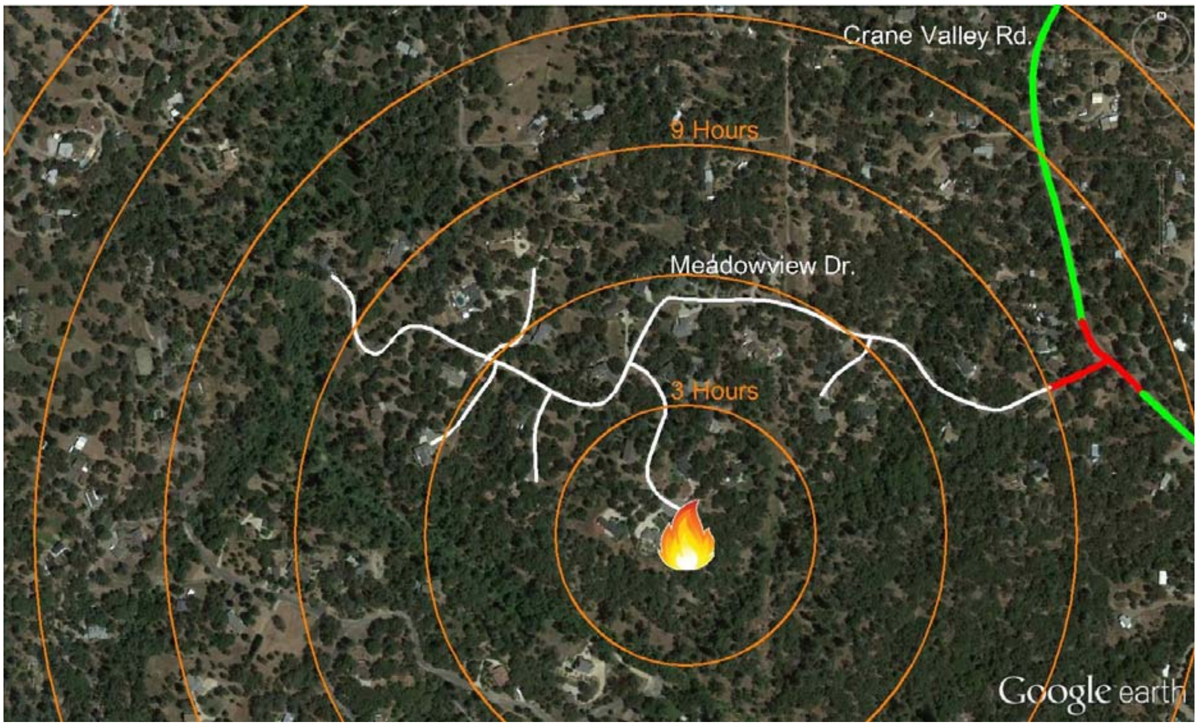
For given slope of 1% to 25%, assumed wind speed of 30 mph, and start of fire at 100 feet south of development:

- Rate of spread =166 feet per minute (1.9 mph)
- Flame length = 69 feet

Case Study: Oakhurst – 4

Figure 5-5 similarly depicts a hypothetical situation where the fire begins 100 feet south of the southernmost property in the development, but under a lower wind speed of 20 mph. Given the proximity of the fire, the development would be threatened sooner than in the first case, but the fire would take a little over 30 minutes to reach the subdivision; this could provide ample time to clear all vehicles if average delay at the through road intersection were 15 seconds or lower per vehicle.

Figure 5-5: Potential Spread of Fire at 20-mph Wind Speed from 100 Feet South of Oakhurst



Parameters

For given slope of 1% to 25%, assumed wind speed of 20 mph, and start of fire at 100 feet south of development:

- Rate of spread = 3 feet per minute (0.034 mph)
- Flame length = 2 feet

Oakhurst Summary

Table 5-3 summarizes various hypothetical fire scenarios for the Oakhurst subdivision. It also shows comparative times to clear all vehicles out of the subdivision under various conditions of delay at the through road intersection. This juxtaposition of fire spread potential against clearance time helps to inform decision makers reviewing development proposals as to whether occupants could be evacuated safely in the event of a fire, under specified conditions.

Table 5-3: Summary of Potential Spread of Fire vs. Clearance Times at Oakhurst

Hypothetical Fire Scenario	Rate of Spread (feet per second)	Time to Reach Development (minutes)	Time to Engulf 50% of Development (Minutes)	Time to Engulf 100% of Development (minutes)
Slope of 1% to 25%, assumed wind speed of 3**0** mph, and start of fire at 5**00** feet south of development	166	3	12	20
Slope of 1% to 25%, assumed wind speed of **20** mph, and start of fire at 5**00** feet west of development	3	150	600	1080
Slope of 1% to 25%, assumed wind speed of 3**0** mph, and start of fire at **100** feet south of development	166	0.5	5	10
Slope of 1% to 25%, assumed wind speed of **20** mph, and start of fire at **100** feet west of development	3	30	300	540

Clearance Times

Delay per Vehicle at Through Road Intersection	Clearance (minutes)
0 seconds	6
5 seconds	13
10 seconds	20
20 seconds	34

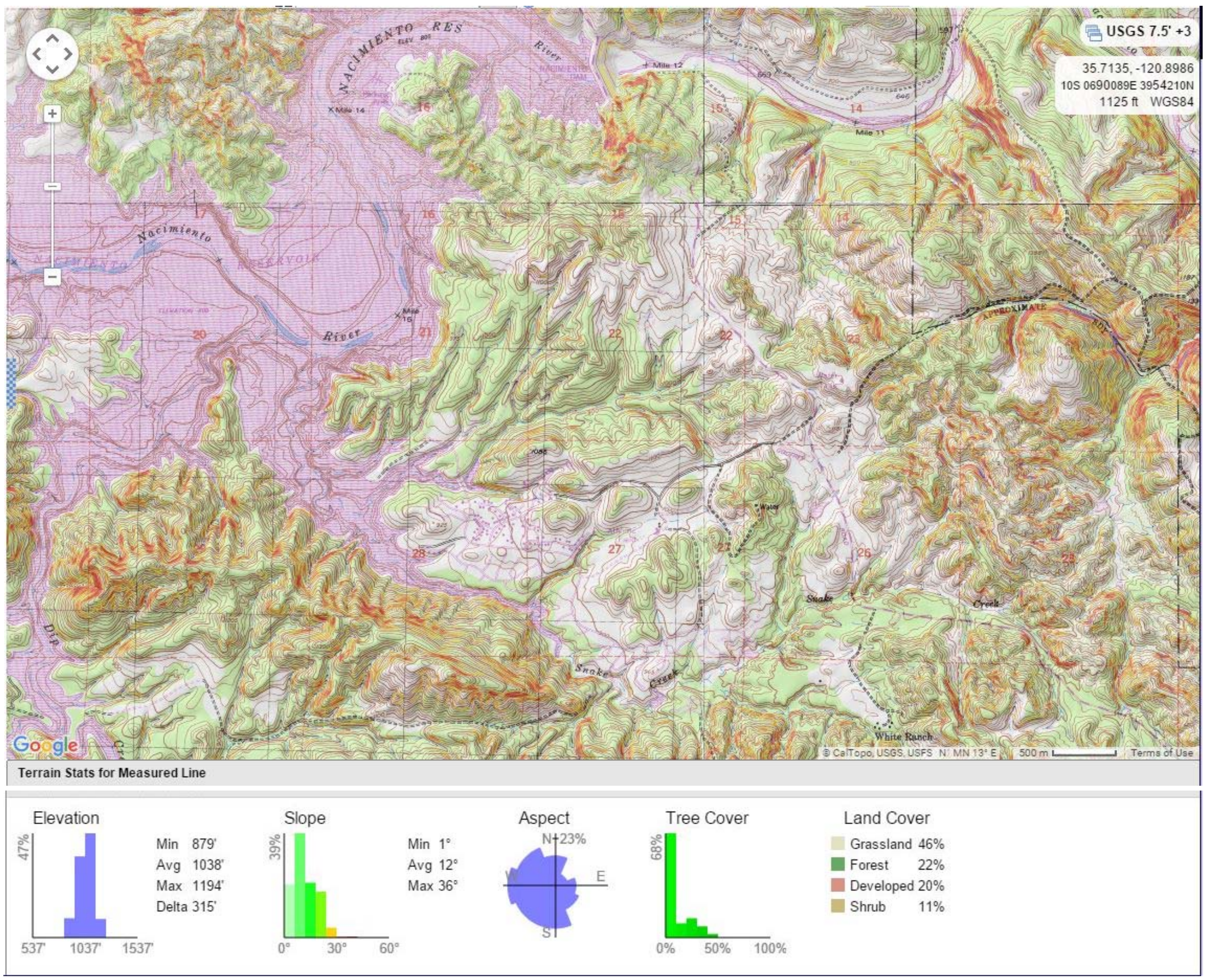
Case Study: Heritage Ranch – 1

Conditions

Figure 5-6 shows existing physical conditions in the vicinity of the Heritage Ranch case study site. In summary, conditions depict the following:

Vegetation: Grass (existing)
Slope: 1% to 25% (existing)
Wind speed: 30 mph (assumed for a “normally severe fire weather day”)

Figure 5-6: Physical Information on Heritage Ranch Study Location



Source: Cal Topo using resources from Google Maps; USGS, and USFS

Associated Look-Up Table

Table 5-4 identifies the appropriate look-up table for the case study site. It also shows the appropriate cell of fire behavior model parameters to use.

Table 5-4: Look-Up Table Applied to Heritage Ranch Study Location

Vegetation: Grass (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 6'/min FL: 3'	ROS: 19'/min FL: 5'	ROS: 42'/min FL: 7'	ROS: 71'/min FL: 9'	ROS: 106'/min FL: 10'	ROS: 144'/min FL: 12'
1-25	ROS: 9'/min FL: 3'	ROS: 23'/min FL: 5'	ROS: 46'/min FL: 7'	ROS: 75'/min FL: 9'	ROS: 110'/min FL: 10'	ROS: 148'/min FL: 12'
26-40	ROS: 29'/min FL: 6'	ROS: 42'/min FL: 7'	ROS: 65'/min FL: 8'	ROS: 95'/min FL: 10'	ROS: 129'/min FL: 11'	ROS: 168'/min FL: 13'
41-55	ROS: 55'/min FL: 8'	ROS: 69'/min FL: 8'	ROS: 91'/min FL: 10'	ROS: 121'/min FL: 11'	ROS: 155'/min FL: 12'	ROS: 194'/min FL: 14'
56-75	ROS: 96'/min FL: 10'	ROS: 109'/min FL: 10'	ROS: 132'/min FL: 11'	ROS: 162'/min FL: 12'	ROS: 196'/min FL: 14'	ROS: 234'/min FL: 15'
>75	ROS: 159'/min FL: 12'	ROS: 173'/min FL: 13'	ROS: 196'/min FL: 14'	ROS: 225'/min FL: 14'	ROS: 260'/min FL: 15'	ROS: 298'/min FL: 16'

Model Parameters

For the given slope range of 1% to 25% and assumed wind speed of 10 mph, the look-up table indicates the following parameters:

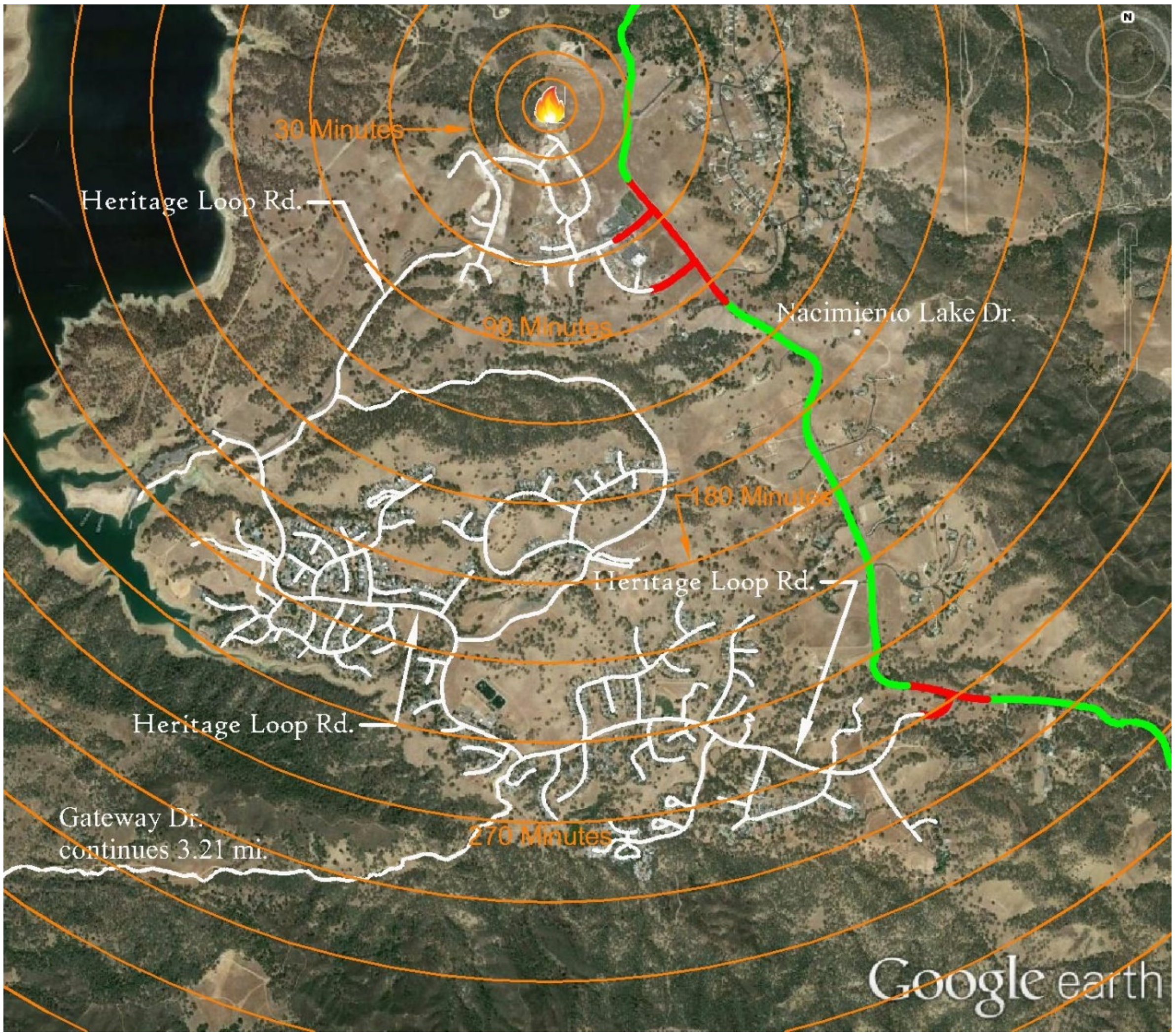
Rate of spread = 75 feet per minute (0.85 mph)
Flame length = 9 feet
Start of fire = 100 to 500 feet from development

Potential Spread of Fire by Time Period

The Heritage Ranch illustration covered three different wind speed scenarios. The scenarios assumed the location of a fire at hypothetical distances of 100 feet and 500 feet from the development. One scenario assumed a best-case wind speed of 10 mph. Figure 5-7 shows how long it would take for the fire to engulf specified sections of the development in 30-minute increments assuming there were no intervention from fire professionals. Results indicate that the fire would reach points farthest north of the development in approximately 10 minutes, overrun the northern (also called western) entrance within 60 minutes, and threaten most of the development within 4 hours.

As shown in Table 5-5, these results compare favorably with the estimated total clearance time of 117 minutes for this development only assuming no further delay at the exit intersection. If prevailing or projected conditions at the through road intersection (for instance from a traffic impact study) indicate that delay per vehicle is 5 seconds at the bottleneck, clearance time would nearly triple to 323 minutes (or 5.4 hours), threatening a large number of residents of the subdivision.

Figure 5-7: Potential Spread of Fire at 10-mph Wind Speed from 500 Feet North of Heritage Ranch



Parameters

For given slope of 1% to 25%, assumed wind speed of 10 mph, and start of fire at 500 feet north of development:

- Rate of spread = 23 feet per minute (0.26 mph)
- Flame length = 5 feet

Table 5-5: Heritage Ranch with Potential Effects of Delay at Main Through Road Intersection

Heritage Ranch: *Level of Delay Assumed per Vehicle at Through Road Intersection (seconds)*	**Normal Travel Time of Farthest Vehicle (seconds)**	**Delay to Farthest Vehicle (seconds)**	**Total Travel Time for Farthest Vehicle (seconds)**	**Number of Vehicles to Clear**	**Average Network/Facility Operating Speed (mph)**	**Total Clearance Time -- No Delay at Through Road Intersection (minutes)**	**Total Clearance Time -- With Delay at Through Road Intersection (minutes)**
0	765	33	799	2,476	6	117	117
5							323
10							529
15							736
20							942

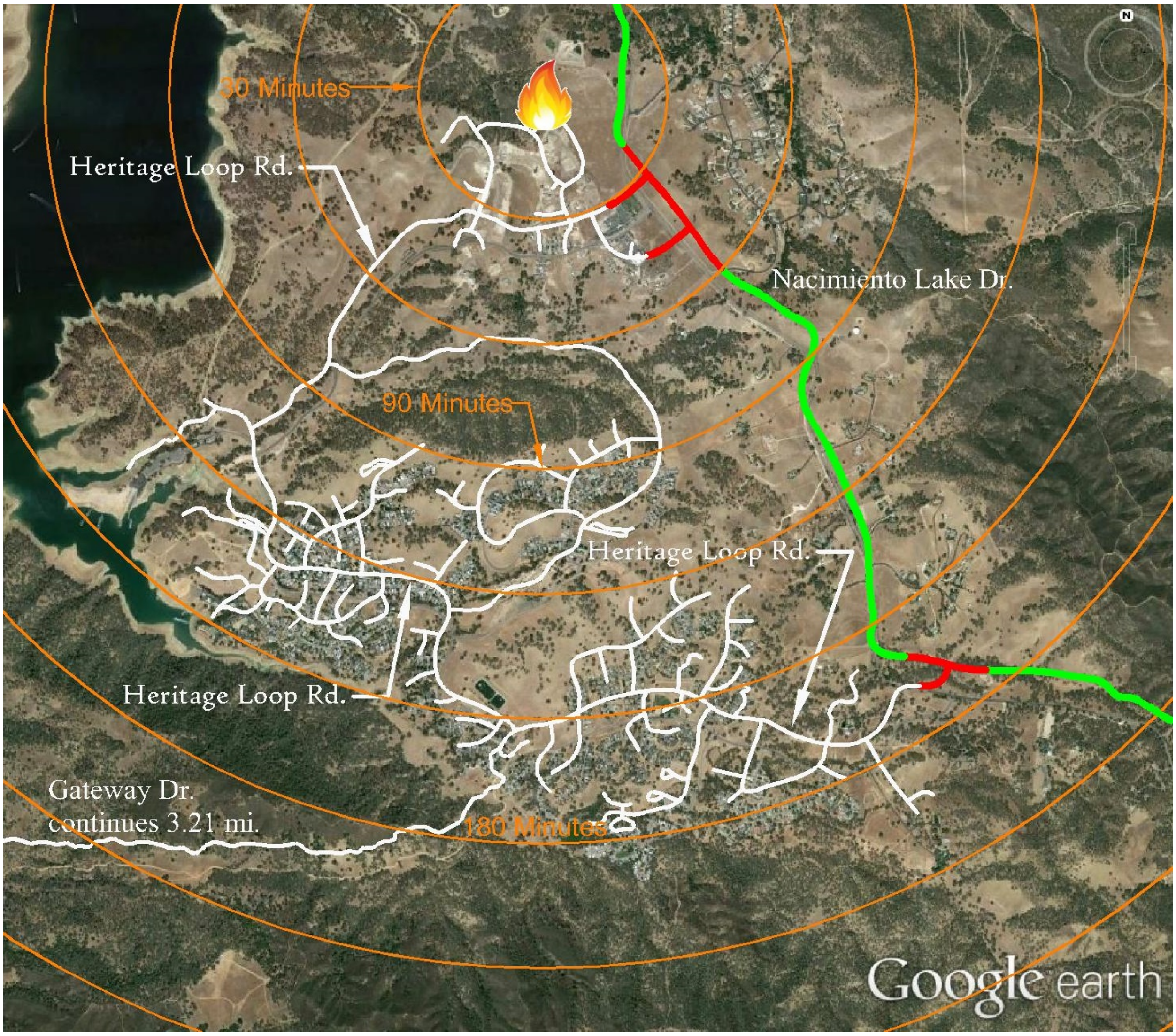
Case Study: Heritage Ranch – 2

Figures 5-8 and 5-9 depict two other hypothetical situations where the fire begins close to the development just 100 feet to the north under higher prevailing wind speeds of 20 mph and 30 mph respectively. The proximity of the fire and the higher wind speeds depict much worse potential outcomes than for the first scenario.

Under the 20 mph scenario, results indicate that the fire would reach points farthest north of the development in approximately 2 minutes and overrun the northern (also called western) entrance within 30 minutes. The fire could engulf the development within 3 hours.

Under the 30 mph scenario, results indicate that the fire would reach points farthest north of the development in approximately 1 minute and overrun the northern (also called western) entrance within 20 minutes. The fire could engulf the development within 2 hours.

Figure 5-8: Potential Spread of Fire at 20-mph Wind Speed from 100 Feet North of Heritage Ranch



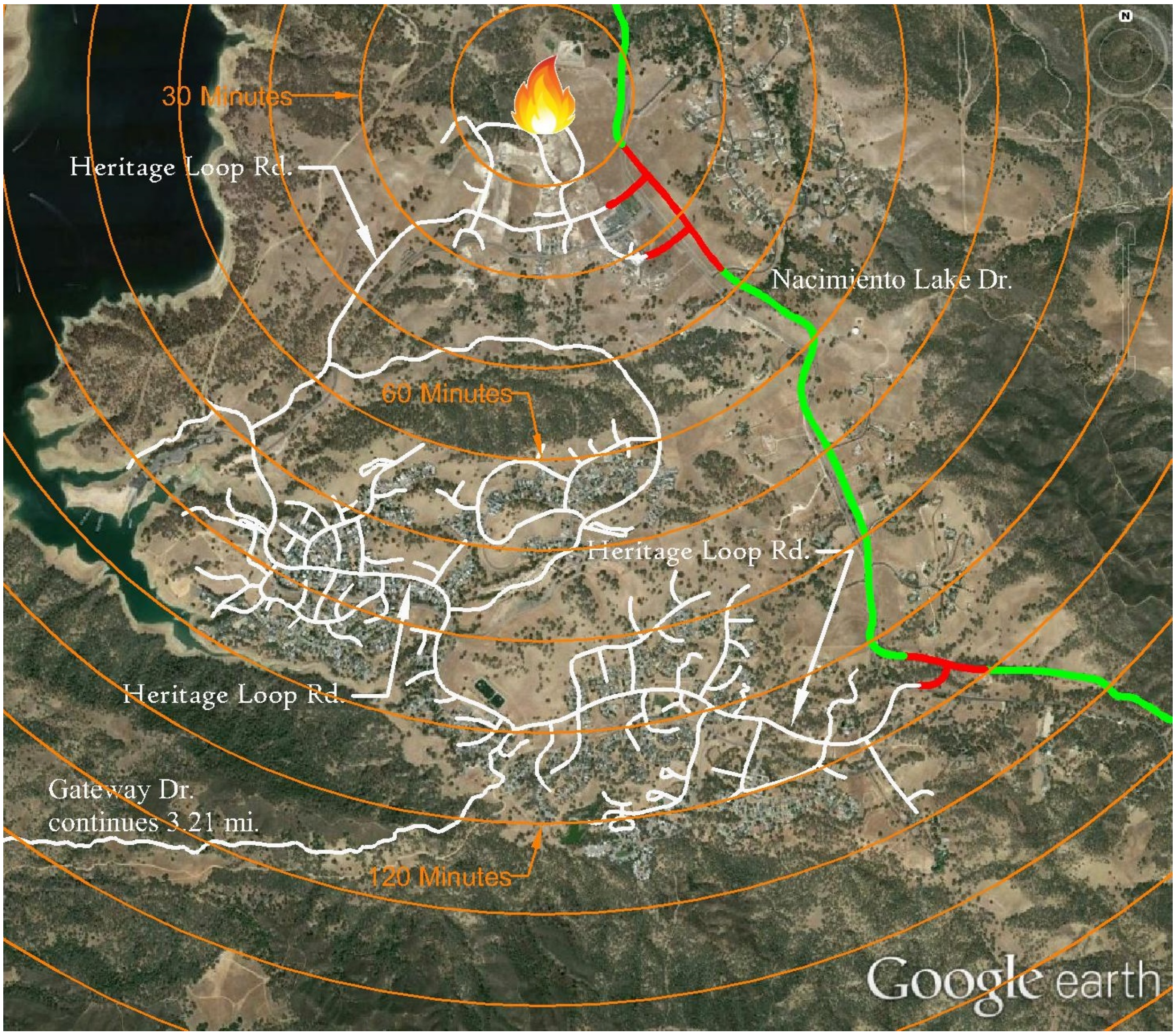
Parameters

For given slope of 1% to 25%, assumed wind speed of 20 mph, and start of fire at 100 feet north of development:

- Rate of spread = 46 feet per minute (0.52 mph)
- Flame length = 7 feet

Case Study: Heritage Ranch – 3

Figure 5-9: Potential Spread of Fire at 30-mph Wind Speed from 100 Feet North of Heritage Ranch



Parameters

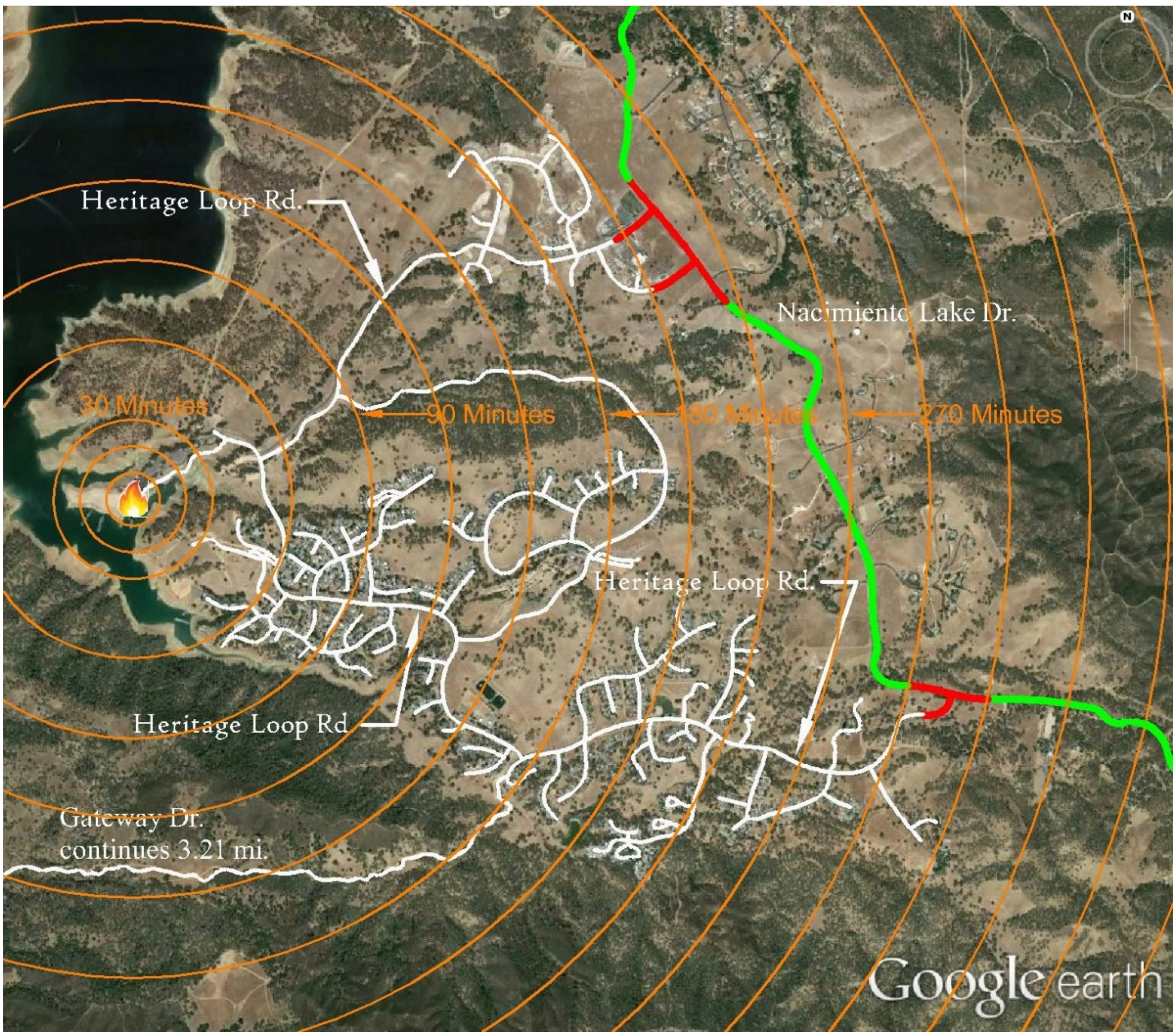
For given slope of 1% to 25%, assumed wind speed of 30 mph, and start of fire at 100 feet north of development:

- Rate of spread = 75 feet per minute (0.85 mph)
- Flame length = 9 feet

Case Study: Heritage Ranch – 4

Figure 5-10 depicts another hypothetical situation where the fire begins 100 feet west of the development under 10 mph wind condition. Given the proximity of the fire, half of the development would be overrun within 1.5 hours and the entire development would be threatened within 5 hours. Figures 5-11 and 5-12 depict two other hypothetical situations where the fire begins further from the development, 500 feet to the west, under higher prevailing wind speeds of 20 mph and 30 mph respectively. The proximity of the fire and the higher wind speeds depict worse potential outcomes than for the previous scenarios.

Figure 5-10: Potential Spread of Fire at 10-mph Wind Speed from 100 Feet West of Heritage Ranch



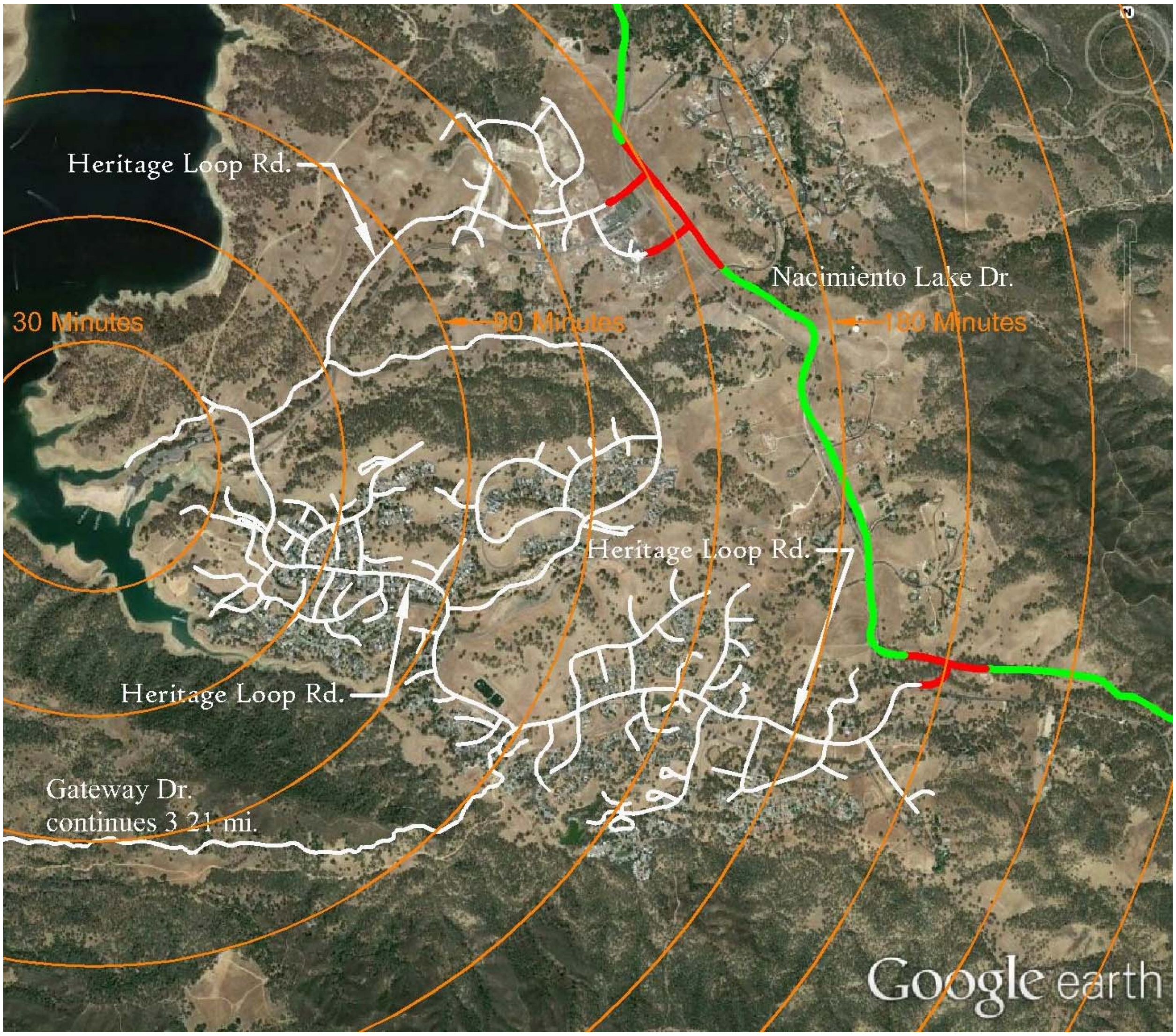
Parameters

For given slope of 1% to 25%, assumed wind speed of 10 mph, and start of fire at 100 feet west of development:

- Rate of spread = 23 feet per minute (0.26 mph)
- Flame length = 5 feet

Case Study: Heritage Ranch – 5

Figure 5-11: Potential Spread of Fire at 20-mph Wind Speed from 500 Feet West of Heritage Ranch



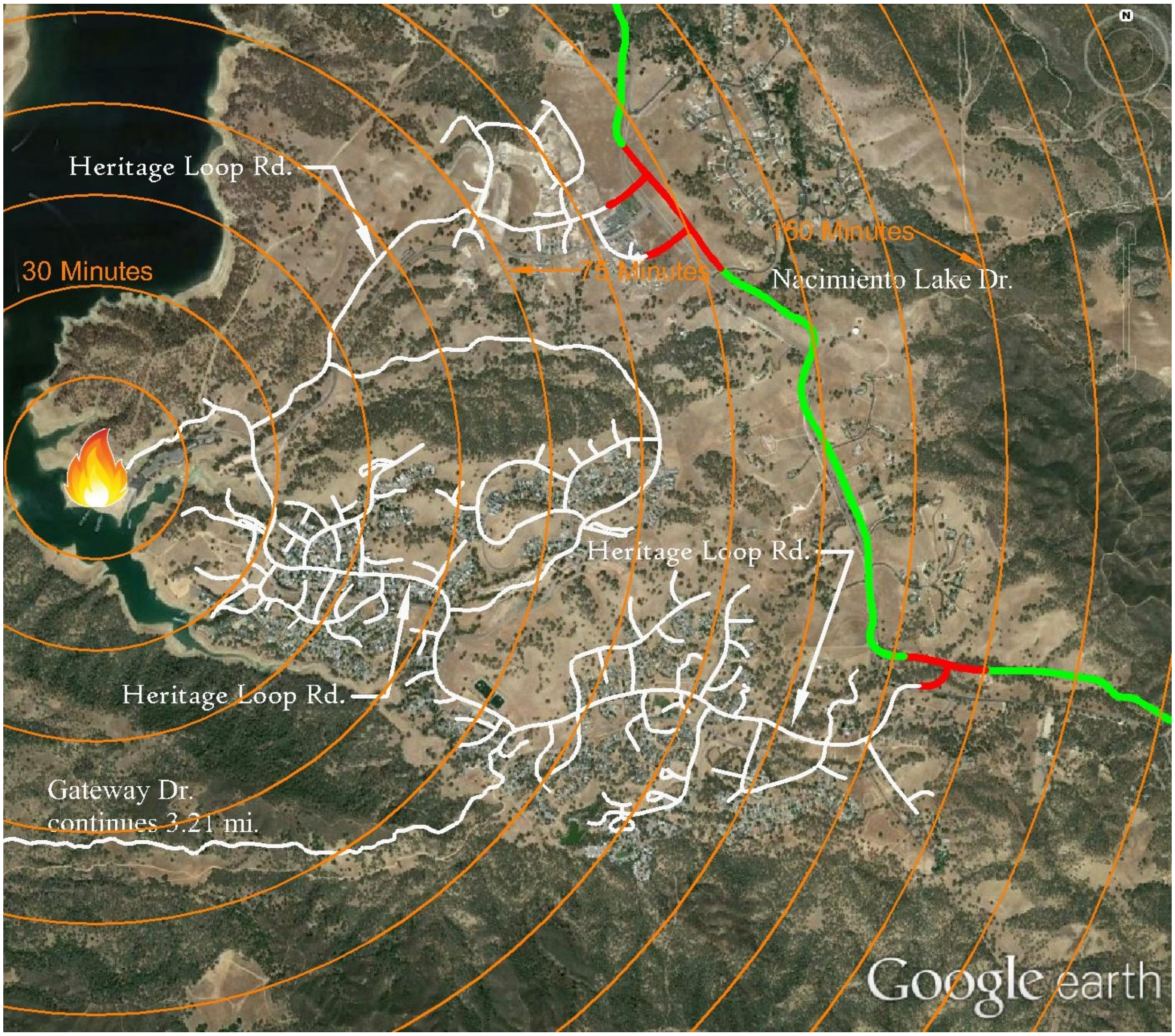
Parameters

For given slope of 1% to 25%, assumed wind speed of 20 mph, and start of fire at 500 feet west of development:

- Rate of spread = 46 feet per minute (0.52 mph)
- Flame length = 7 feet

Case Study: Heritage Ranch – 6

Figure 5-12: Potential Spread of Fire at 30-mph Wind Speed from 500 Feet West of Heritage Ranch



Parameters

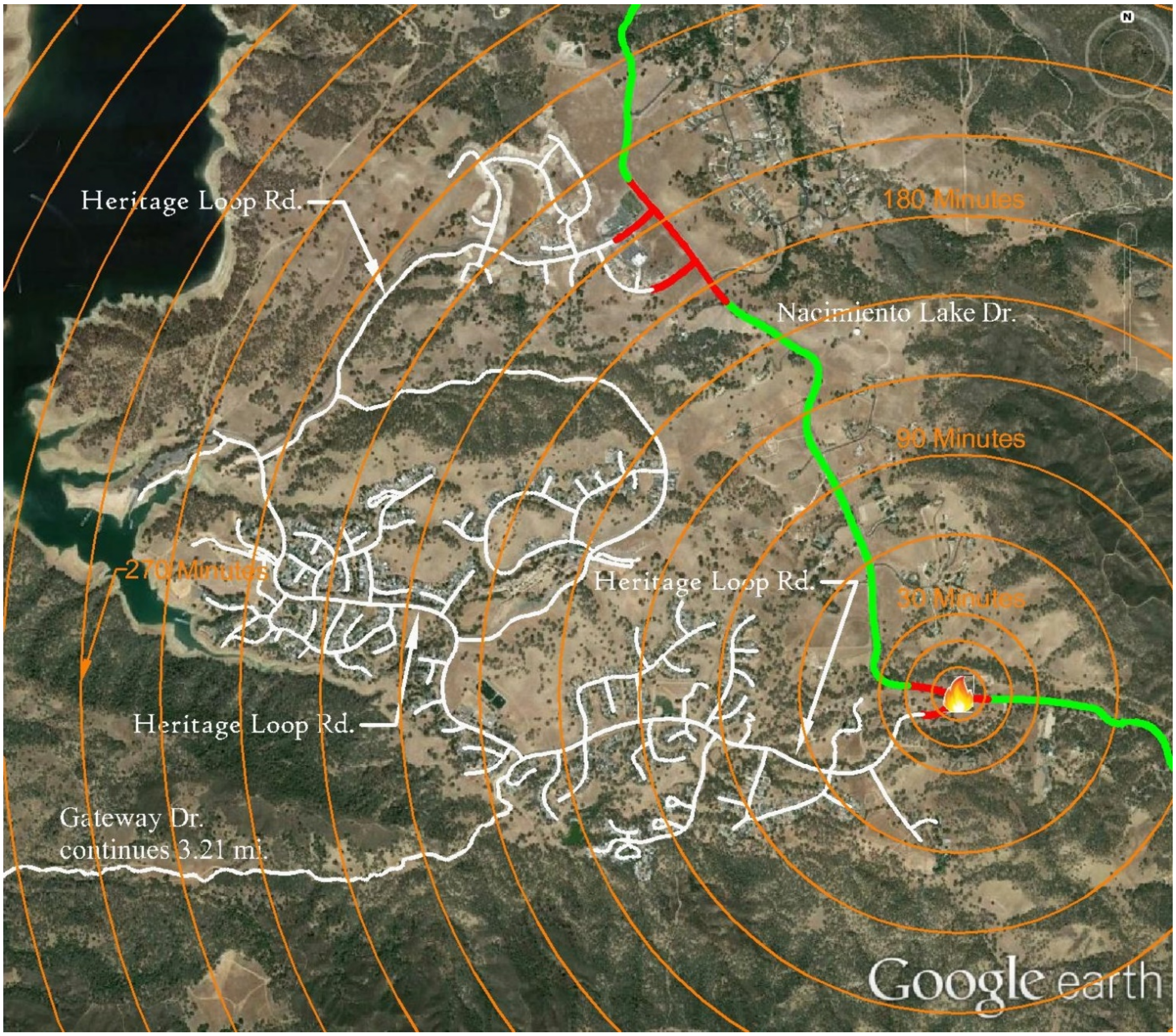
For given slope of 1% to 25%, assumed wind speed of 30 mph, and start of fire at 500 feet west of development:

- Rate of spread = 75 feet per minute (0.85 mph)
- Flame length = 5 feet

Case Study: Heritage Ranch – 7

Figure 5-13 similarly depicts a hypothetical situation where the fire begins 100 feet east of the development. Given the proximity of the fire, half of the development would be overrun within 1.5 hours and the entire development would be threatened within 4 hours.

Figure 5-13: Potential Spread of Fire at 10-mph Wind Speed from 100 Feet East of Heritage Ranch



Parameters

For given slope of 1% to 25%, assumed wind speed of 10 mph, and start of fire at 100 feet east of development:

- Rate of spread = 23 feet per minute (0.26 mph)
- Flame length = 5 feet

Summary

Table 5-6 summarizes the various hypothetical fire scenarios at the Heritage Ranch subdivision. It also shows comparative times to clear all vehicles out of the subdivision under various conditions of delay at the through road intersection. It is noteworthy that it would only take 5 seconds of delay at the through road intersection for any of the scenarios to depict the potential for catastrophic consequences.

Table 5-6: Summary of Potential Spread of Fire vs. Clearance Times at Heritage Ranch

Hypothetical Fire Scenario (Slope of 1% to 25%)	**Rate of Spread (feet per minutes)**			**Time to Engulf 100% of Development (minutes)**
Wind speed of **10** mph, and start of fire at **500** feet north of development	23			270
Wind speed of **20** mph, and start of fire at **100** feet north of development	46			180
Wind speed of **30** mph, and start of fire at **100** feet north of development	75			120
Wind speed of **10** mph, and start of fire at **100** feet west of development	23			300
Wind speed of **20** mph, and start of fire at **500** feet west of development	46			210
Wind speed of **30** mph, and start of fire at **500** feet west of development	75			120
Wind speed of **10** mph, and start of fire at **100** feet east of development	23			240

Clearance Times

Delay per Vehicle at Through Road Intersection	**Clearance (minutes)**
0 seconds	117
5 seconds	323
10 seconds	529
15 seconds	736
20 seconds	942

6.0 STUDY RECOMMENDATIONS

Based on findings from application of the evacuation and fire spread models to both hypothetical and actual case study locations, the Cal Poly team has formulated the following recommendations:

1. Replace Existing Table of Maximum Road Lengths

The existing table of maximum road lengths specified in the Code of California Regulations, Title 14, Section 1273.09 Dead-End Roads regulation should be replaced, following sufficient beta testing, with the ***procedure for applying the planning tool*** described below, for the following reasons:

- Maximum dead-end road lengths are based solely on parcel size.
- The standards assume that subdivisions are only for single-family residential uses.
- The standards place no limit on the number of lots in subdivisions.
- The standards allow for stacking of multiple roadways within maximum length limits.
- The standards do not provide for reasonable evacuation times for all road length categories.
- The standards do not consider other land uses such as commercial uses, apartments, or schools.
- The standards do not take into account potential long-term land use intensification.
- There is no clearly stated enforcement mechanism or penalty for non-compliance.

2. Seek Collaboration

CAL FIRE and the Board of Forestry & Fire Protection should seek collaboration during beta testing with partner organizations such as the Governor's Office of Emergency Services (Cal OES), Governor's Office of Planning and Research (OPR), League of California Cities, California State Association of Counties (CSAC), Rural County Representatives of California (RCRC), California Fire Chiefs Association (CalChiefs), and National Fire Protection Association (NFPA). Beta testing should be supported by training workshops organized by CAL FIRE. Collaborative attention should be given during beta testing to identification of sustainable funding mechanisms offsetting and financing hazard mitigation costs, such as Mello-Roos Community Facilities Districts.

3. New Regulation

When finalized, the recommended planning tool procedure should ***fully replace*** the current dead-end street length regulation through ***state adoption of a new regulation requiring application of the procedure*** by local agencies in:

a. ***Single-access*** subdivisions proposed in an SRA area categorized as either a ***Moderate*** or ***High*** Fire Hazard Severity Zone (FHSZ),
b. ***All*** subdivisions proposed in an SRA area categorized as a ***Very High*** FHSZ, and

c. ***All*** single-access subdivisions in a state recommended and locally adopted ***Very High*** FHSZ within an LRA.

Implementation of the planning tool procedure should be supported by online and workshop training hosted by CAL FIRE.

4. Monitor Implementation of the Planning Tool

Implementation of the planning tool procedure by local agencies should be monitored over time by CAL FIRE and the Board of Forestry & Fire Protection to determine compliance, with attention to:

a) Identification of incentives and penalties needed to secure compliance,
b) Results in the field indicating relative effectiveness of the new procedure, and
c) Formulation of periodic regulatory adjustments reflecting lessons learned from its application.

5. Senate Bill 1241

The preceding recommendations should be tied in with Senate Bill 1241 (2012). General plans govern land use intensification and are especially relevant to single-access subdivision land use capacity and occupancy considerations.

As mentioned at the beginning of this report, tentative map approval for a new subdivision is contingent on the proposal being consistent with the general plan. Legislation enacted in 2012 (Senate Bill 1241) requires that additional mandatory findings be made before tentative map approval can be granted to a proposed subdivision in an area located within an SRA or a locally adopted Very High FHSZ, specifically (1) that the design and location of the subdivision are consistent with applicable regulations adopted by the Board of Forestry and Fire Protection pursuant to PRC Sections 4290 and 4291, (2) that structural fire protection and suppression services will be available for the subdivision, and (3) that, to the extent practicable, ingress and egress for the subdivision meet the regulations regarding road standards for fire equipment access adopted pursuant to PRC Section 4290 and any applicable local ordinance. Special attention should be given to implementing these requirements for additional mandatory findings under Senate Bill 1241.

6. Enforcement of Mitigation Requirements

Attention should also be given to the enforcement of mitigation requirements that emerge from implementation of the planning tool procedure and are adopted as a condition of tentative map approval for a new subdivision. Consideration should be given to possible mechanisms to bring about more uniform compliance, addressing non-compliance situations and seeking options (such as fines and other penalties) at the local level that go beyond case law. A mandatory appeal process to a higher authority such as the State Board of Forestry and Fire Protection should be established.

7. Parallel Adaptation in All Hazards Contexts

CAL FIRE and the Board of Forestry & Fire Protection should work with agencies such as those identified in Recommendation #2 above for possible parallel adaptation of the proposed new single access subdivision review procedure in All Hazards contexts, specifically in areas potentially impacted by other natural hazards for which the state has existing mandated mapping responsibilities, e.g., the State Seismic Hazards Mapping Act, Earthquake Fault Zones Mapping Act (Alquist-Priolo), and Central Valley Flood Protection Planning District.

This page intentionally left blank

Appendix 1: Focused Literature Review

Single-Access Subdivisions Assessment Project:

Developing a Planning Tool for Evaluating Proposed Developments Accessible by Dead-End Roads

Prepared for

CAL FIRE and the California Board of Forestry and Fire Protection

By

California Polytechnic State University, San Luis Obispo

CAL POLY
SAN LUIS OBISPO

June 2016

This page intentionally left blank

Introduction

At the start of this project, the Cal Poly team conducted a focused search to identify literature directly relevant to the issue of establishing controls over proposed subdivisions accessible by dead-end roads, including:

- Any available records from the time of the adoption in California of PRC 4290 and accompanying regulations (CCR 1273.09) that explain the underlying basis for the specified maximum road lengths;
- Any available literature relating to efforts by other jurisdictions (within or outside the United States) to establish requirements for proposed subdivisions accessible by dead-end roads.

In addition, the team sought relevant literature relating to:

- The ability to predict the time taken for occupants to exit from, and fire-fighting equipment/personnel to enter, a subdivision in the event of a wildfire;
- The ability to predict fire behavior within a WUI, and particularly the rate at which a wildfire might overtake occupants seeking to evacuate, and fire-fighting equipment/personnel seeking to enter, a subdivision.

Findings

Subdivision Controls

In general, although there was occasional mention of the sometimes deadly consequences of constructing subdivisions accessible by dead-end roads, the team found almost nothing in the literature relating to the basis for controls over the construction of such subdivisions.

A review of records relating to the adoption in California of PRC 4290 and accompanying regulations (CCR 1270 et seq.) produced general statements such as:

- "Lengths of dead-end roads have been limited, based on the potential traffic volume, to reduce the risk of entrapment."
- "The parameters that lead to increased risk for civilians and fire fighters on dead-end roads are the volume of traffic using that road, the length of road, width of road, grade and fuel types. High density developments, in SRA, on long dead-end roads have the real potential of becoming major catastrophes."
- "Section 1273 .09 sets a limit on the length of dead—end roads. This again was selected to consider safe emergency ingress and egress during a wildfire. The distances were selected to consider the number of possible vehicles, fire spread, and the fire intensity under heavy fuel conditions."

(California State Board of Forestry, 1990)

However, nothing was found that explained in detail how the Board of Forestry came up with the maximum road lengths specified in the regulation governing dead-end roads (CCR 1270.09)

Similarly, documents relating to the adoption of California's Fire Safe Program failed to provide this explanation; rather they included statements such as:

- "During each phase of a large development project in high fire-hazard areas, the developer should be required to provide at least two access routes until all phases of development and the permanent road system can be completed." (9042.4)
- "Road and street networks, whether public or private, shall provide for safe access for emergency wildland fire equipment and civilian evacuation concurrently, and shall provide unobstructed traffic circulation during a wildfire emergency. Two separate points of ingress/egress are preferred." (9044.2)

Moving beyond just California, the National Fire Protection Association (NFPA) publishes an extensive set of codes and standards, many of which are adopted, partially or in their entirety, by state and local jurisdictions. The latest versions say very little about dead-end roads in WUI areas (NFPA, 2012). In a 2005 article, using NFPA codes as an example, Cova questions whether fire-prone communities should have a maximum occupancy, pointing out that "egress standards are currently defined in terms of minimum exit-road widths, or a minimum number of exits, without regard to how many people might rely on the exits" (p.99). He raises the analogy of the link drawn in building egress codes between the maximum occupancy of an enclosed space and the required number, capacity, and arrangement of exits. Building on this analogy, Cova proposes codes based on simple look-up tables for residential loading factors (e.g., road length per household) and the minimum number and capacity of exits, taking into account the level of wildfire hazard (low, moderate, or high+). One of the look-up tables has as its basis "a desired minimum evacuation time" which Cova asserts "should be at most 30 min" in a high (or greater) fire hazard community (p.104), but he fails to explain where this number came from.

A 2014 article by Bond and Mercer specifically investigates subdivision design as a mitigation tool that "can manage and lessen the impact on humans and the environment" of bushfires (the Australian term for wildfires). The authors review a number of subdivision policies currently adopted by jurisdictions that are mostly in Australia but also include three in the United States (the State of Montana, the state of Florida, and Bannock County, Idaho). A table identifies six policy requirements, currently adopted by Australian jurisdictions, for no-through roads (the Australian term for dead-end roads). Several specify maximum road lengths (typically "not to exceed 200 metres") and/or the number of properties that may be serviced.

However, neither in the article by Bond and Mercer nor in any other literature, was the Cal Poly team able to find an explanation of the rationale underlying the various specific requirements (e.g., governing road lengths) adopted to address proposed subdivisions accessible by dead-end roads.

Bibliography Relating to Subdivision Controls

Bannock County (2011). Urban-Wildland Interface Code: Fire Protection Requirements For Residential Development in Hazardous Fire Areas. Pocatello, Idaho: Bannock County

Bihari, M., Hamin, E., and Ryan, R. (2012). "Understanding the Role of Planners in Wildfire Preparedness and Mitigation." ISRN Forestry, 10.5402/2012/253028, 1-12.
Online publication date: 1-Jan-2012.

Bond, T. and Mercer, D. (2014). "Subdivision Policy and Planning for Bushfire Defence: A Natural Hazard Mitigation Strategy for Residential Peri-Urban Regions in Victoria, Australia." Geographical Research, 10.1111/1745-5871.12040, 6-22.

California State Board of Forestry (1990). October 10, 1990 California Board of Forestry Proceedings on Rule Making for Public Resources Code 4290. Sacramento: Board of Forestry.

Cova, T. (2005). "Public Safety in the Urban–Wildland Interface: Should Fire-Prone Communities Have a Maximum Occupancy?." Nat. Hazards Rev., 10.1061/(ASCE)1527-6988(2005)6:3(99), 99-108.

Duerksen, C., Elliott, D., and Anthony, P. (2011). Addressing Community Wildfire Risk: A Review and Assessment of Regulatory and Planning Tools, Final Report. Quincy, MA: Fire Protection Research Foundation.

Florida Department of Agriculture and Consumer Services, Division of Forestry (2010). Wildfire Risk Reduction in Florida: Home Neighborhood, and Community Best Practices. Tallahassee, FL: Florida Department of Agriculture and Consumer Services.

Gill, A. and Stephens, S. (2009). "Scientific and social challenges for the management of fire-prone wildland–urban interfaces." Environmental Research Letters, 10.1088/1748-9326/4/3/034014, 034014.

Headwaters Economics (2016). Land Use Planning to Reduce Wildfire Risk: Lessons fromFive Western Cities. http://headwaterseconomics.org/wphw/wp-content/uploads/Planning_Lessons_Full_Report_Web.pdf

International Fire Code Institute (2003). Urban-wildland interface code. Whittier, CA: International Fire Code Institute.

Kano, M., Kelley, M., and Hashemi, M. (2011). "Local emergency evacuation planning in California, USA: a comparison with the hurricane states." International Journal of Emergency Management, 10.1504/IJEM.2011.040400, 74.
Online publication date: 1-Jan-2011.

Montana Department of Natural Resources and Conservation (2009). Guidelines for Development Within the Wildland-Urban Interface. Helena, MT: DNRC

National Fire Protection Association (2012). Standard for Fire Protection Infrastructure for Land development in Wildland, Rural, and Suburban Areas, NFPA 1141. Quincy, MA: NFPA.

National Fire Protection Association (2013). Community Wildfire Safety Through Regulation: A Best Practices Guide for Planners and Regulators. Quincy, MA: NFPA.

Schwab, J. (2014). Planning for Post-Disaster Recovery: Next Generation, PAS 576. Chicago: American Planning Association.

Schwab, J. and Meck, S. with Simone, J. (2005). Planning for Wildfires, PAS 529/530. Chicago: American Planning Association.

Wolshon, B. and Marchive, E. (2007). "Emergency Planning in the Urban-Wildland Interface: Subdivision-Level Analysis of Wildfire Evacuations." Journal of Urban Planning and Development, 10.1061/(ASCE)0733-9488(2007)133:1(73), 73-81.

Access and Fire Behavior

The modeling of subdivision access (egress or ingress) was based on techniques that are standard in the field of transportation engineering/planning, as published in National Research Council (2010, especially Chaps 15, 16, 17). The conceptual framework for selecting and organizing relevant information as well as analyzing the evacuation of residents was provided by a study by KLD Engineering (2012) of the Diablo Canyon Nuclear Power Plant for Pacific Gas and Electric Company. The study focused on planning for evacuation based on estimates of time to clear residents, which in turn depends on the number and geographical distribution of residents.

Inputs and assumptions utilized for the designation of Fire Hazard Severity Zones (Sapsis, 2007) provided the basis for fire behavior predictions throughout this project. The modeling of fire behavior, used in developing look-up tables, employed NEXUS software, based on underlying principles described in Scott, J. H. and Reinhardt, E. D. 2001. The NEXUS software itself is described in Scott (1999). Fuel moisture conditions related to a "normally severe fire weather day" were developed in part using BehavePlus software (Heinsch and Andrews, 2010), while fuel model selection drew on Scott and Burgan (2005) and canopy fuel inputs on Landfire Data. The sample photos of vegetative fuel types came from Fire and Environmental Research Applications Team (2016).

Bibliography Relating to Access and Fire Behavior

Transportation

Cova, T.J. and Johnson, J.P. (2003) A network flow model for lane-based evacuation routing. Transportation Research Part A: Policy and Practice, 37(7): 579-604.

Ensley, James Oliver (2012). Application of Highway Capacity Manual 2010 Level-of-Service Methodologies for Planning Deficiency Analysis. Master's Thesis, University of Tennessee. http://trace.tennessee.edu/utk_gradthes/1373

KLD Engineering (2012). Diablo Canyon Power Plant: Development of Evacuation Time Estimates, Final Report. Hauppauge, NY: KLD Engineering

National Research Council. Transportation Research Board. (2010). HCM 2010 : Highway Capacity Manual. Washington, D.C.: Transportation Research Board.

Washburn, Scott S., McLeod, Douqlas S., & Courage, Kenneth G. (2002). Adaptation of highway capacity manual 2000 for planning-level analysis of two-lane and multilane highways in Florida. Transportation Research Record, 1802, 62-68.

Zegeer, John D., Blogg, Miranda, Nguyen, Khang, & Vandehey, Mark. (2008). Default values for highway capacity and level-of-service analyses. Transportation Research Record, 2071, 35-43. doi: 10.3141/2071-05

Evacuation During Wild Fires

Church, R.L. and Cova, T.J. (2000). Mapping evacuation risk on transportation networks using a spatial optimization model. Transportation Research Part C: Emerging Technologies, 8(1-6): 321-336.

Cova, T.J. and Church, R.L. (1997) Modelling community evacuation vulnerability using GIS. International Journal of Geographical Information Science, 11(8): 763-784.

Cova, T.J. Dennison, P.E. Kim, T.H. and Moritz, M.A. (2005) Setting wildfire evacuation trigger-points using fire spread modeling and GIS. Transactions in GIS, 9(4): 603-617..

Cova, T.J. and Johnson, J.P. (2002) Microsimulation of neighborhood evacuations in the urban-wildland interface. Environment and Planning A, 34(12): 2211-2229. Published, 2002.

Cova, T.J. Theobald, D.M, Norman, J. and Siebeneck, L.K. (2013) Mapping wildfire evacuation vulnerability in the western US: the limits of infrastructure. Geojournal, 78(2): 273-285.

Dennison, P.E. Cova, T.J. and Moritz, M.A. (2007) WUIVAC: a wildland-urban interface evacuation trigger model applied in strategic wildfire scenarios. Natural Hazards, 40, 181-199.

Fryer, G. Dennison, P.E. and Cova, T.J. Wildland (2013). Firefighter entrapment avoidance: modeling evacuation triggers using WUIVAC. International Journal of Wildland Fire.

Larsen, J.C. Dennison, P.E. Cova, T.J. Jones, C. (2011) Evaluating dynamic wildfire evacuation trigger buffers using the 2003 Cedar Fire. Applied Geography, 31: 12-19.

Fire Behavior

Fire & Environmental Research Applications Team (2016). Natural Fuels Photo Series. Available at http://www.fs.fed.us/pnw/fera/research/fuels/photo_series/index.shtml

Heinsch, F. A.; Andrews, P. L. (2010). BehavePlus fire modeling system, version 5.0: Design and Features, General Technical Report RMRS-GTR-249. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

LandFire Data Distribution Site. Available at http://www.landfire.gov/viewer/

Sapsis, D. (2007). Guidelines for Fire Hazard Zoning Review and Validation. Available at http://frap.fire.ca.gov/projects/hazard/FHSZ_review_instructionsv1_3b.pdf

Scott, Joe H. (1999). NEXUS: A system for assessing crown fire hazard. Fire Management Notes 59(2): 20-24.

Scott, J.H., and Burgan, R.E. (2005). Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. USDA Forest Service General Technical Report RMRS-GTR-153.

Scott, J. H. and Reinhardt, E. D. (2001). Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Scott, J. H. and Reinhardt, E. D. (2002). Estimating canopy fuels in conifer forests. Fire Management Today 62(4): 45-50.

Appendix 2: Additional Details on Access Modeling

Single-Access Subdivisions Assessment Project:

Developing a Planning Tool
for Evaluating Proposed Developments
Accessible by Dead-End Roads

Prepared for

CAL FIRE and the California Board of Forestry and Fire Protection

By

California Polytechnic State University, San Luis Obispo

CAL POLY
SAN LUIS OBISPO

June 2016

This page intentionally left blank

TABLE OF CONTENTS

1.0 INTRODUCTION

The Additional Details on Access Modeling Appendix provides the following information:

1. A technical summary of the data and calculations incorporated into the access model developed for this study;
2. A prototypical application of the access model to a hypothetical case study involving a residential subdivision served by a stacked single access road (i.e., a dead-end road with other dead-end roads attached);
3. Details of the model's application to a set of hypothetical case studies involving single-access subdivisions within the various parcel size categories covered by the existing dead-end road regulations (CCR Title 14 section 1273.9);
4. Details of the model's application to a variety of existing subdivisions selected as real life case studies;
5. Comparisons of various situations reflected in the real life case studies; and
6. Background data used in the modeling.

2.0 ACCESS MODEL APPLICATION METHODOLOGY

STEP 1.1: Input Data

The application of the Access Model requires taking a map of a subdivision and reducing it into a roadway schematic of links and nodes. At a minimum, the information needed along each link includes:

1. Length of link (feet)
2. Directional lanes
3. Posted speed limit OR design speed (mph)
4. Number of houses (existing or proposed)

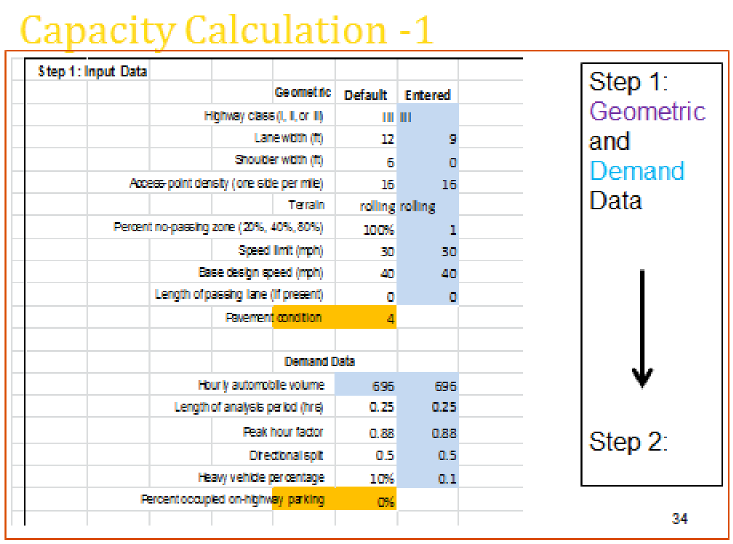
Several application examples follow.

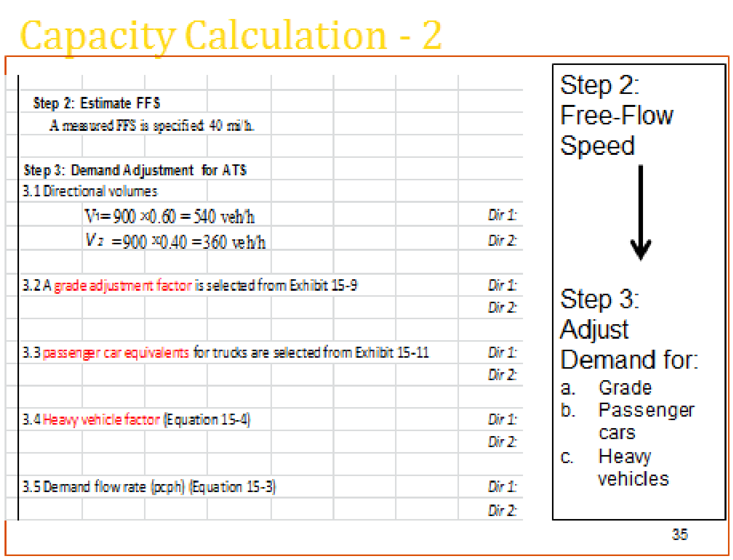
Additional information required for background calculations of roadway capacity includes:
1. Lane width (feet)
2. Shoulder width (feet)
3. Access-point density (one side per mile)
4. Terrain (level, rolling)
5. Percent no-passing zone (20%, 40%, 80%)
6. Length of passing lane (if present)

STEP 1.2: Capacity Calculation

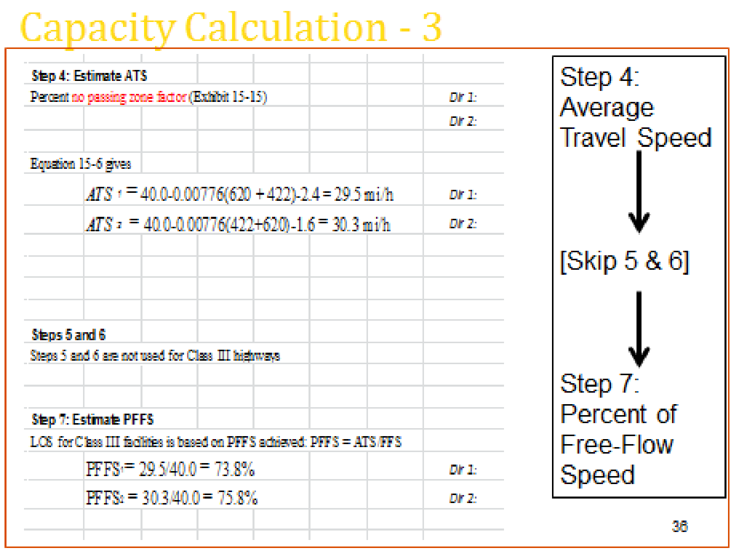
This is a multi-step process involving Highway Capacity Methods of the 2010 Highway Capacity Manual (HCM). Procedures are adapted from Chapter 15 of the 2010 HCM.

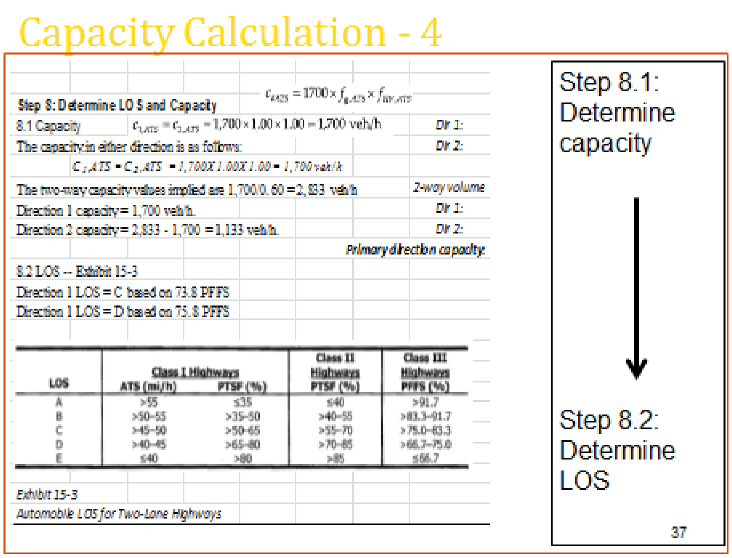
The following tables demonstrate the four calculations included in the process of capacity calculation:





Capacity calculation steps continued:

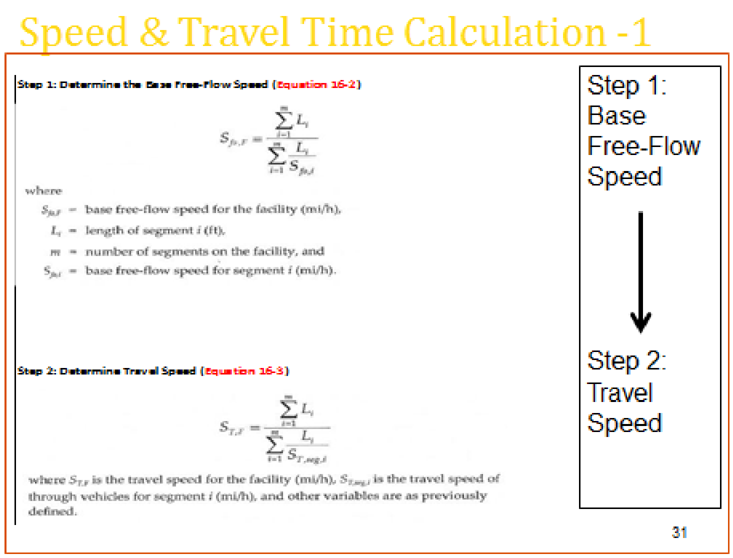


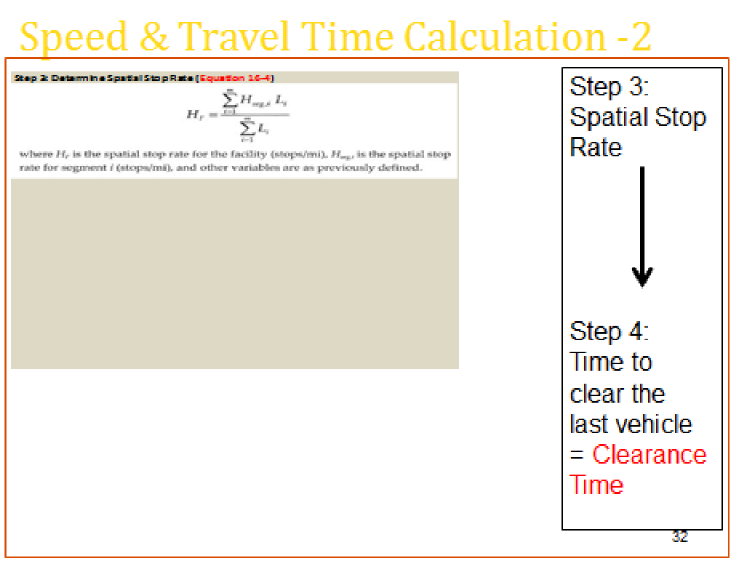


LOS	Class I Highways ATS (mi/h)	Class I Highways PTSF (%)	Class II Highways PTSF (%)	Class III Highways PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7

STEP 1.3: Speed and Travel Time Calculation

This is a multi-step process involving Highway Capacity Methods of the 2010 Highway Capacity Manual (HCM). Procedures are adapted from Chapter 16 of the 2010 HCM.





STEP 1.4: Clearance Time

1. Convert number of houses on segment to number of cars to evacuate using UC Census average number of vehicles per house (2.2) for suburban and rural areas
2. Adjust for RVs and trailers in the mix by dividing number of vehicles by a default factor of 0.9, i.e. 10 percent heavy vehicles in the mix
3. Calculate directional queue length as number of vehicles times 25 feet {for average vehicle length with headway gap between vehicles) divided by number of directional lanes
4. Calculate delayed running time as directional queue length divided by segment length multiplied by segment running time
5. Calculate cumulative delay by summing over the series of segments the maximum of zero and the difference between delayed running time and segment running time
6. Bring in segment running speed from Steps 1 thru 3 of HCM Methods.
7. Calculate average roadway speed as the weighted average of segment running speeds
8. Identify the combination of segments that add up to the longest distance to the exit onto the main through road
9. Sum respective segment running times and delays for longest delayed vehicle route and sum for longest delayed vehicle
10. Calculate total vehicle clearance as the product of delay to traverse the through road intersection (of 2.5 seconds) and total number of vehicles plus total time for longest delayed vehicle

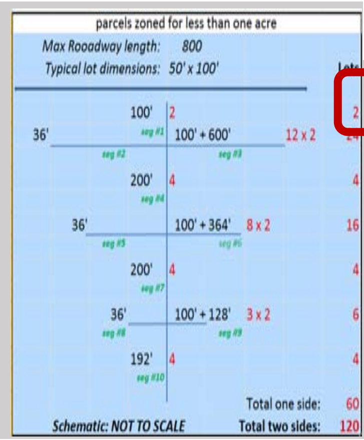
This page intentionally left blank

3.0 THE PROTOTYPE: STACKED SINGLE ACCESS EXAMPLE

The graphic below is an image of the modelling tool input page as it appears in the MS Excel program.

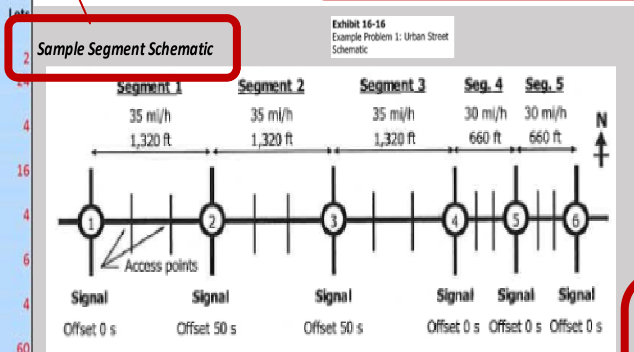
This sample schematic illustrates how a schematic is prepared.

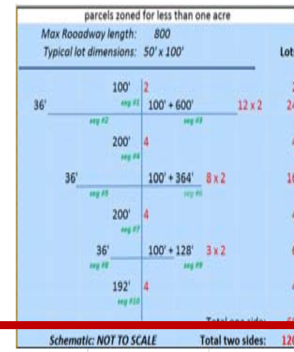
The Application Schematic is generated based on input data entered into the model and represents the road network being analyzed.



<< << Schematic Key

Application Schematic >>>





Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

The output data in this portion of the tool are the modeling outcomes resulting from entry of input data in blue cells. Total clear time is listed in the cell on the right.

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	47	68	293	13.4

Input

Number of Segments: 10

Summary

Average Network/Facility Operating Speed (MPH): 6.6

Segment	Houses on Segment	Segment Length (L_s)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	100	25	37.4	2.73	1	1	10	244	7	3.	5.4
Segment 2	24	700	25	37.4	19.09	2	1	59	1467	40	20.	9.2
Segment 3	24	700	25	37.4	19.09	2	1	59	1467	40	20.	9.2
Segment 4	8	236	25	37.4	6.44	2	1	20	489	13	6.	6.4
Segment 5	16	464	25	37.4	12.65	3	1	39	978	27	14.	7.1
Segment 6	16	464	25	37.4	12.65	3	1	39	978	27	14.	7.1
Segment 7	8	236	25	37.4	6.44	3	1	20	489	13	6.	5.1
Segment 8	6	228	25	37.4	6.22	4	1	15	367	10	3.	4.6
Segment 9	6	228	25	37.4	6.22	4	1	15	367	10	3.	4.6
Segment 10	8	228	25.0	37.4	6.22	4	1	20	489	13	7.	4.2

	PBFS	LOS		21.8	46.7
Facility	27%	F	Longest segment combo? (Y=1)	Longest combo run time	Longest combo delay
Segment 1	22%	F	1	2.7	6.7
Segment 2	37%	E			
Segment 3	37%	E			
Segment 4	25%	F	1	6.4	13.3
Segment 5	28%	F			
Segment 6	28%	F			
Segment 7	21%	F	1	6.4	13.3
Segment 8	18%	F			
Segment 9	18%	F			
Segment 10	17%	F	1	6.2	13.3

Input data is entered in blue cells.

Calculations shown in red cells based on input data.

Output data for each segment in green cells.

Orange cells reflect intermediate results of the steps in the calculations under the model (no manual inputs required)

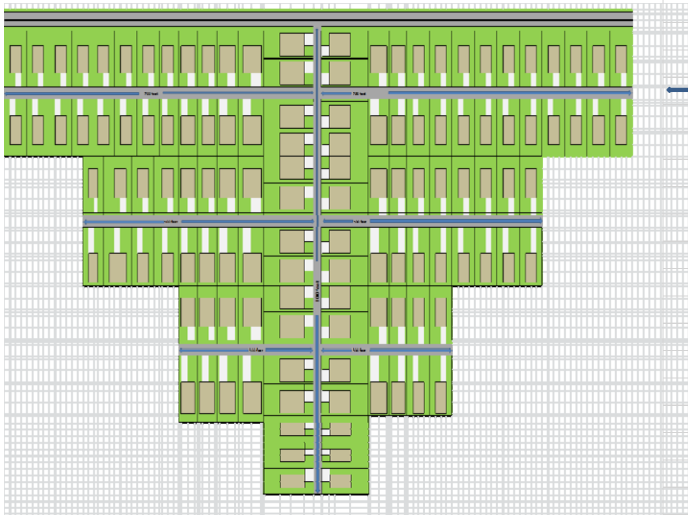
Application to Hypothetical Cases

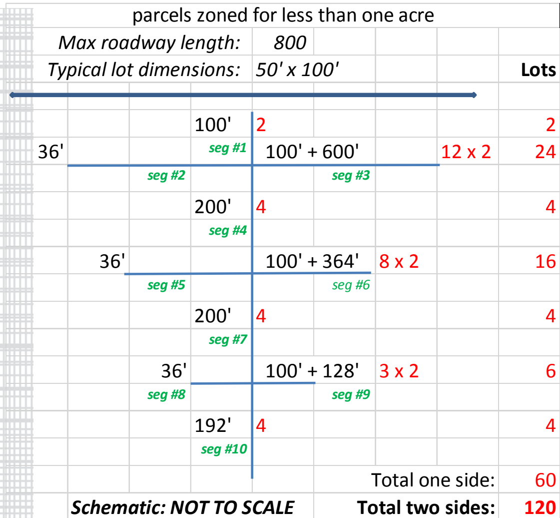
Appendix 2-Table 1: Summary of Potential Effects of Delay at Main Through Road Intersection on Hypothetical Cases

Development Conditions	**Normal travel time of farthest vehicle**	**Delay to farthest vehicle**	**Total travel time for farthest vehicle (sec)**	**Number of vehicles to clear**	**Average network/facility operating speed (mph)**	**Total Clearance Time -- no delay at through road intersection (min)**	**Total Clearance Time -- with delay at through road intersection (min)[1]**
Various parcel sizes -- without mitigation options							
< 1acre; 120 DU	22	47	68	293	7	**13**	**87**
1 to 4.99 acres; 44 DU	36	10	46	112	14	**6**	**34**
5 to 19.99 acres; 34 DU	72	23	95	83	20	**5**	**26**
20 acres +; 36 DU	144	47	191	88	22	**7**	**29**
Parcels zoned for less than 1 acre -- with potential mitigation options							
240 dwelling units (DU)	22	93	115	587	4	**26**	**173**
120 DU; 1 exit lane	22	47	68	293	7	**13**	**87**
120 DU; *2 exit lanes*	22	23	45	293	9	**13**	**86**
120 DU; *1 lane; 2 exits*	22	47	68	147	8	**7**	**44**
120 DU + *school;* 1 lane	22	127	148	538	5	**25**	**159**
120 DU + *school; 2 lanes*	22	63	85	538	7	**24**	**158**
120 DU + *school; 2 exits*	22	130	152	269	5	**14**	**81**

[1] Assumes an average of 15 seconds of delay per vehicle accumulated from first exiting to last exiting vehicle.

Parcels zoned for less than 1 acre





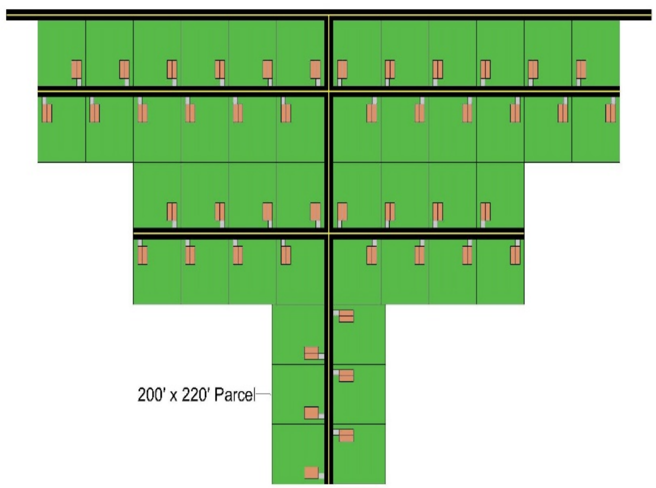
Input

Summary

Number of Segments:	10							Average Network/Facility Operating Speed (MPH):				6.6
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (Exhibit 17-11)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	*Segment Operation Speed*
Segment 1	4	100	25	37.4	2.73	1	1	10	244	7	3.9	5.4
Segment 2	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 3	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 4	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 5	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 6	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 7	8	236	25	37.4	6.44	3	1	20	489	13	6.9	5.1
Segment 8	6	228	25	37.4	6.22	4	1	15	367	10	3.8	4.6
Segment 9	6	228	25	37.4	6.22	4	1	15	367	10	3.8	4.6
Segment 10	8	228	25.0	37.4	6.22	4	1	20	489	13	7.1	4.2

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	47	68	293	13.4

Parcels zoned for 1 acre to 5 acres



parcels zoned for 1 acre to 4.99 acres				
Max roadway length:	*1320*			
Typical lot dimensions:	*200' x 220'*			**Lots**
	220'	0		0
36'		200' + 900'	6 x 2	12
	440'	0		0
36'		200' + 424'	4 x 2	8
	588'	3		3
				0
			Total one side:	23
Schematic: NOT TO SCALE			**Total two sides:**	**46**

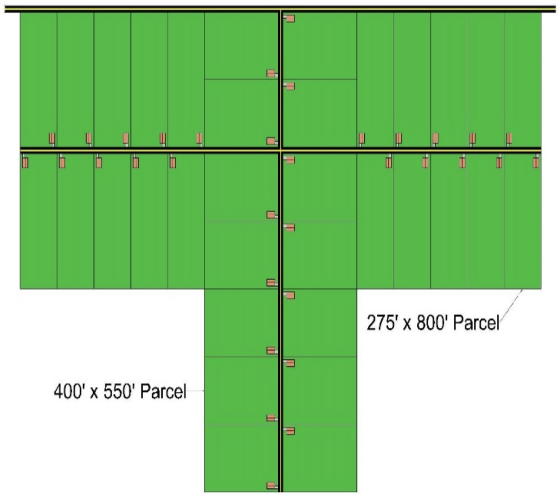
Input

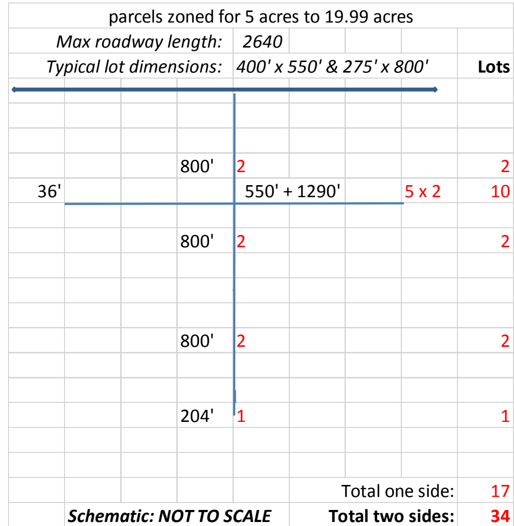
Summary

Number of Segments:	***10***							**Average Network/Facility Operating Speed (MPH):**				**14.4**
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (**Exhibit 17-11**)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	***Segment Operation Speed***
Segment 1	0	220	25	37.4	6.00	1	1	0	0	0	0.0	12.5
Segment 2	12	1100	25	37.4	30.00	2	1	29	733	20	0.0	17.9
Segment 3	12	1100	25	37.4	30.00	2	1	29	733	20	0.0	17.9
Segment 4	0	476	25	37.4	12.98	2	1	0	0	0	0.0	13.0
Segment 5	8	624	25	37.4	17.02	3	1	20	489	13	0.0	12.1
Segment 6	8	624	25	37.4	17.02	3	1	20	489	13	0.0	12.1
Segment 7	6	624	25	37.4	17.02	3	1	15	367	10	0.0	12.1
Segment 8												

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
36	10	46	112	5.5

Parcels zoned for 5 acres to 20 acres





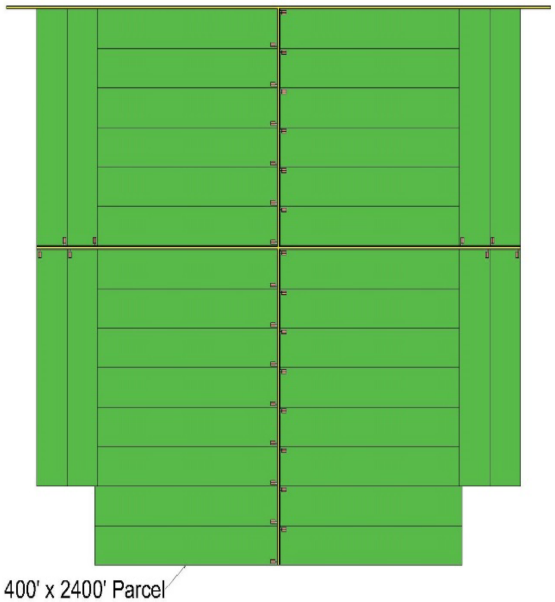
Input

Summary

Number of Segments:	10							Average Network/Facility Operating Speed (MPH):				20.1
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	800	25	37.4	21.82	1	1	10	244	7	0.0	19.6
Segment 2	10	1840	25	37.4	50.18	2	1	24	611	17	0.0	20.2
Segment 3	10	1840	25	37.4	50.18	2	1	24	611	17	0.0	20.2
Segment 4	10	1840	25	37.4	50.18	2	1	24	611	17	0.0	20.2
Segment 5												

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
72	23	95	83	5.1

Parcels zoned for 20 acres or larger



parcels zoned for 20 acres or larger			
Max roadway length:	*5280*		
Typical lot dimensions:	*400' x 2400'*		**Lots**
	2400'	6	6
36'	2400' + 480'	2 x 2	4
	2400'	6	6
	444'	2	2
		Total one side:	18
Schematic: NOT TO SCALE		**Total two sides:**	**36**

Input

Summary

Number of Segments:	***10***							**Average Network/Facility Operating Speed (MPH):**				**21.9**
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (**Exhibit 17-11**)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	***Segment Operation Speed***
Segment 1	12	2400	25	37.4	65.45	1	1	29	733	20	0.0	22.9
Segment 2	4	2880	25	37.4	78.55	2	1	10	244	7	0.0	21.7
Segment 3	4	2880	25	37.4	78.55	2	1	10	244	7	0.0	21.7
Segment 4	16	2880	25	37.4	78.55	2	1	39	978	27	0.0	21.7
Segment 5												

Far veh time	**Far veh delay**	**Tot Far time (sec)**	**Vehs**	**Total Clear (min)**
144	47	191	88	6.9

Varied Treatments on Parcels zoned for less than 1 acre

240 Dwelling Units

Input — **Summary**

Number of Segments:	*10*							**Average Network/Facility Operating Speed (MPH):**				4.3
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (Exhibit 17-11)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	*Segment Operation Speed*
Segment 1	8	100	25	37.4	2.73	1	1	20	489	13	10.6	3.5
Segment 2	48	700	25	37.4	19.09	2	1	117	2933	80	60.9	5.2
Segment 3	48	700	25	37.4	19.09	2	1	117	2933	80	60.9	5.2
Segment 4	16	236	25	37.4	6.44	2	1	39	978	27	20.2	4.2
Segment 5	32	464	25	37.4	12.65	3	1	78	1956	53	40.7	4.4
Segment 6	32	464	25	37.4	12.65	3	1	78	1956	53	40.7	4.4
Segment 7	16	236	25	37.4	6.44	3	1	39	978	27	20.2	3.6
Segment 8	12	228	25	37.4	6.22	4	1	29	733	20	13.8	3.5
Segment 9	12	228	25	37.4	6.22	4	1	29	733	20	13.8	3.5
Segment 10	16	228	25.0	37.4	6.22	4	1	39	978	27	20.4	3.1

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	93	115	587	26.4

120 Dwelling Units & 2 Exit Lanes

Input

Summary

Number of Segments:	*10*							**Average Network/Facility Operating Speed (MPH):**				**9.0**
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (Exhibit 17-11)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	*Segment Operation Speed*
Segment 1	4	100	25	37.4	2.73	1	2	10	122	3	0.6	7.3
Segment 2	24	700	25	37.4	19.09	2	2	59	733	20	0.9	14.9
Segment 3	24	700	25	37.4	19.09	2	2	59	733	20	0.9	14.9
Segment 4	8	236	25	37.4	6.44	2	2	20	244	7	0.2	8.6
Segment 5	16	464	25	37.4	12.65	3	2	39	489	13	0.7	10.1
Segment 6	16	464	25	37.4	12.65	3	2	39	489	13	0.7	10.1
Segment 7	8	236	25	37.4	6.44	3	2	20	244	7	0.2	6.5
Segment 8	6	228	25	37.4	6.22	4	2	15	183	5	0.0	5.1
Segment 9	6	228	25	37.4	6.22	4	2	15	183	5	0.0	5.1
Segment 10	8	228	25.0	37.4	6.22	4	2	20	244	7	0.4	5.1

Far veh time	**Far veh delay**	**Tot Far time (sec)**	**Vehs**	**Total Clear (min)**
22	23	45	293	**13.0**

120 Dwelling Units & 2 Exits

Input

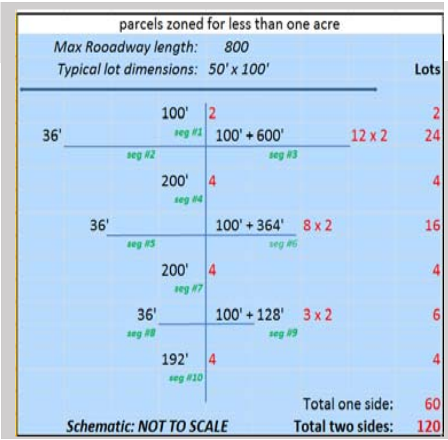
Summary

Number of Segments:	**10**	Average Network/Facility Operating Speed (MPH):	7.6

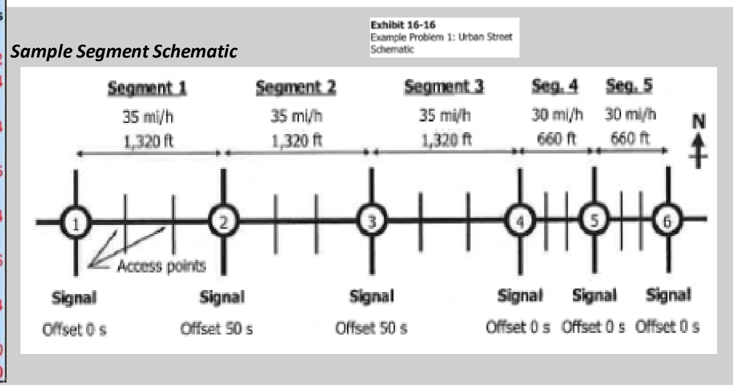
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	100	25	37.4	2.73	1	1	10	244	7	3.9	5.4
Segment 2	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 3	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 4	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 5	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 6	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 7	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 8	6	228	25	37.4	6.22	2	1	15	367	10	3.8	7.1
Segment 9	6	228	25	37.4	6.22	2	1	15	367	10	3.8	7.1
Segment 10	8	228	25.0	37.4	6.22	1	1	20	489	13	7.1	8.0

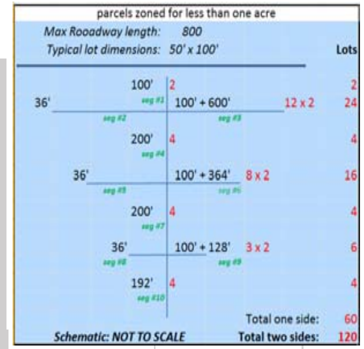
	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	47	68	147	7.3

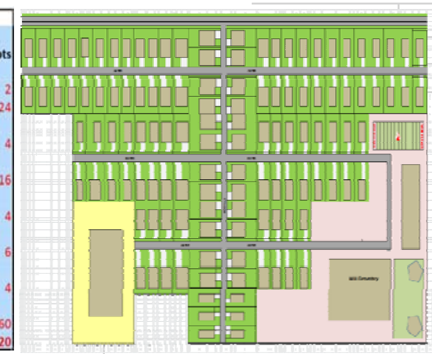
120 Dwelling Units & School & 1 Exit Lane



<<<< Schematic Key **Application Schematic >>>**







Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	127	148	538	24.9

Input

School: access from links 6 and 9; 240 kids = 50% INTERNAL & 50% EXTERNAL = 120 kids -30 on bus = 90 picked + 10 staff = 100 veh @ 50 veh per link OUT

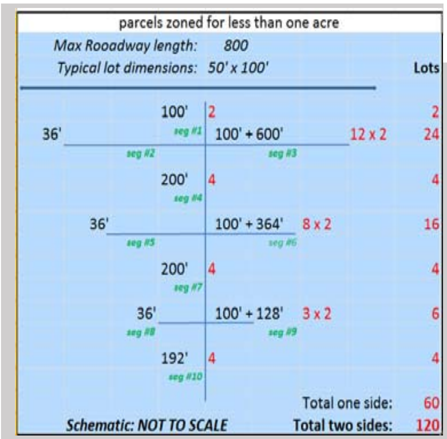
Summary

Number of Segments: ***10***

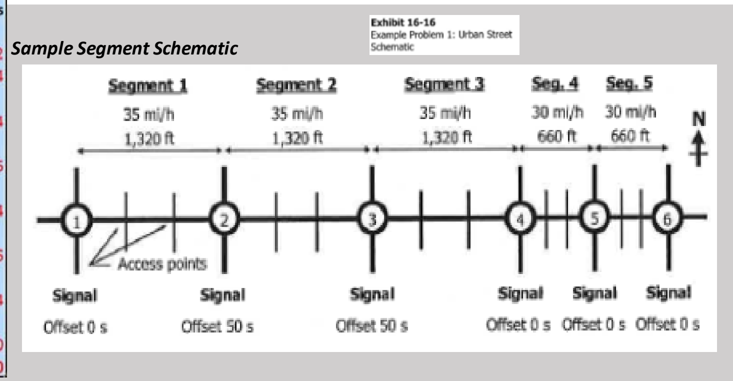
Average Network/Facility Operating Speed (MPH): 4.6

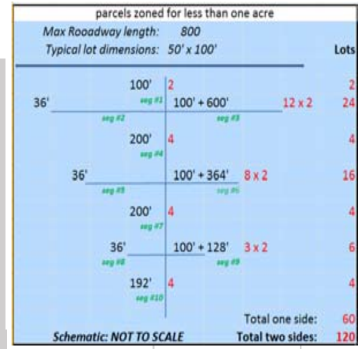
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	100	25	37.4	2.73	1	1	10	244	7	3.9	5.4
Segment 2	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 3	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 4	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 5	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 6	66	464	25	37.4	12.65	3	1	161	4033	110	97.3	2.5
Segment 7	8	236	25	37.4	6.44	3	1	20	489	13	6.9	5.1
Segment 8	6	228	25	37.4	6.22	4	1	15	367	10	3.8	4.6
Segment 9	56	228	25	37.4	6.22	4	1	137	3422	93	87.1	1.3
Segment 10	8	228	25.0	37.4	6.22	4	1	20	489	13	7.1	4.2

120 Dwelling Units & School & 2 Exit Lanes



<<<< Schematic Key **Application Schematic >>>**





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	63	85	538	23.9

Input

School: access from links 6 and 9; 240 kids = 50% INTERNAL & 50% EXTERNAL = 120 kids -30 on bus = 90 picked + 10 staff = 100 veh @ 50 veh per link OUT

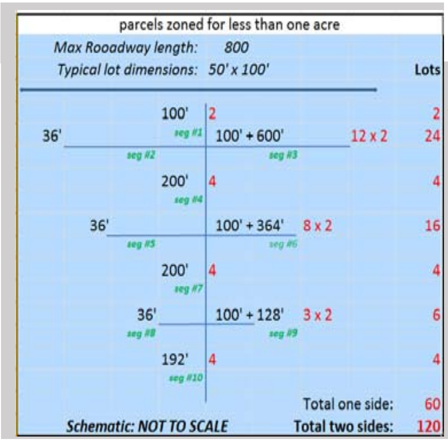
Summary

Number of Segments: **10**

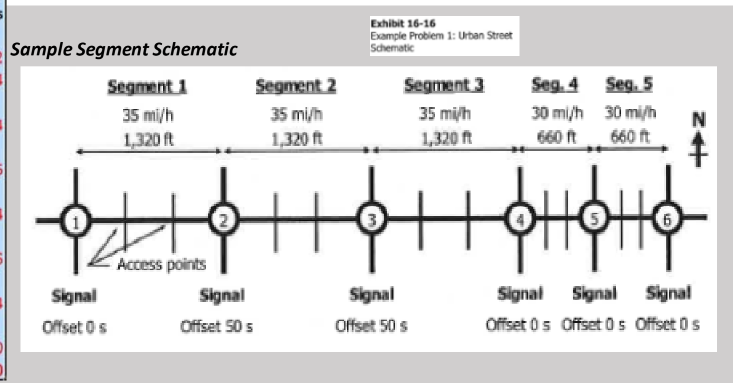
Average Network/Facility Operating Speed (MPH): **6.9**

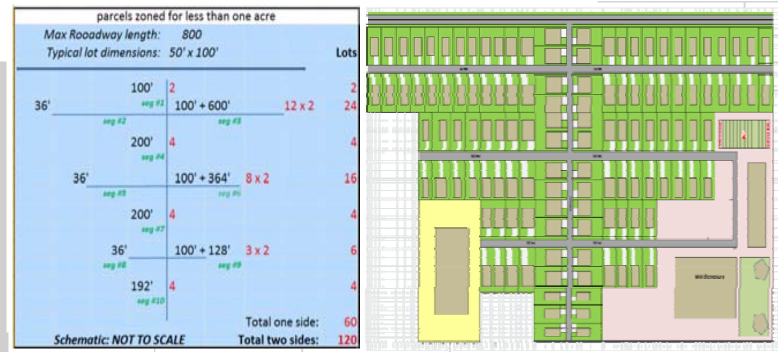
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	100	25	37.4	2.73	1	2	10	122	3	0.6	7.3
Segment 2	24	700	25	37.4	19.09	2	2	59	733	20	0.9	14.9
Segment 3	24	700	25	37.4	19.09	2	2	59	733	20	0.9	14.9
Segment 4	8	236	25	37.4	6.44	2	2	20	244	7	0.2	8.6
Segment 5	16	464	25	37.4	12.65	3	2	39	489	13	0.7	10.1
Segment 6	66	464	25	37.4	12.65	3	2	161	2017	55	42.3	4.3
Segment 7	8	236	25	37.4	6.44	3	2	20	244	7	0.2	6.5
Segment 8	6	228	25	37.4	6.22	4	2	15	183	5	0.0	5.1
Segment 9	56	228	25	37.4	6.22	4	2	137	1711	47	40.4	2.2
Segment 10	8	228	25.0	37.4	6.22	4	2	20	244	7	0.4	5.1

120 Dwelling Units & School & 2 Exits



<<<< Schematic Key Application Schematic >>>





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
22	130	152	269	13.8

Input

School: access from links 6 and 9; 240 kids = 50% INTERNAL & 50% EXTERNAL = 120 kids -30 on bus = 90 picked + 10 staff = 100 veh @ 50 veh per link OUT

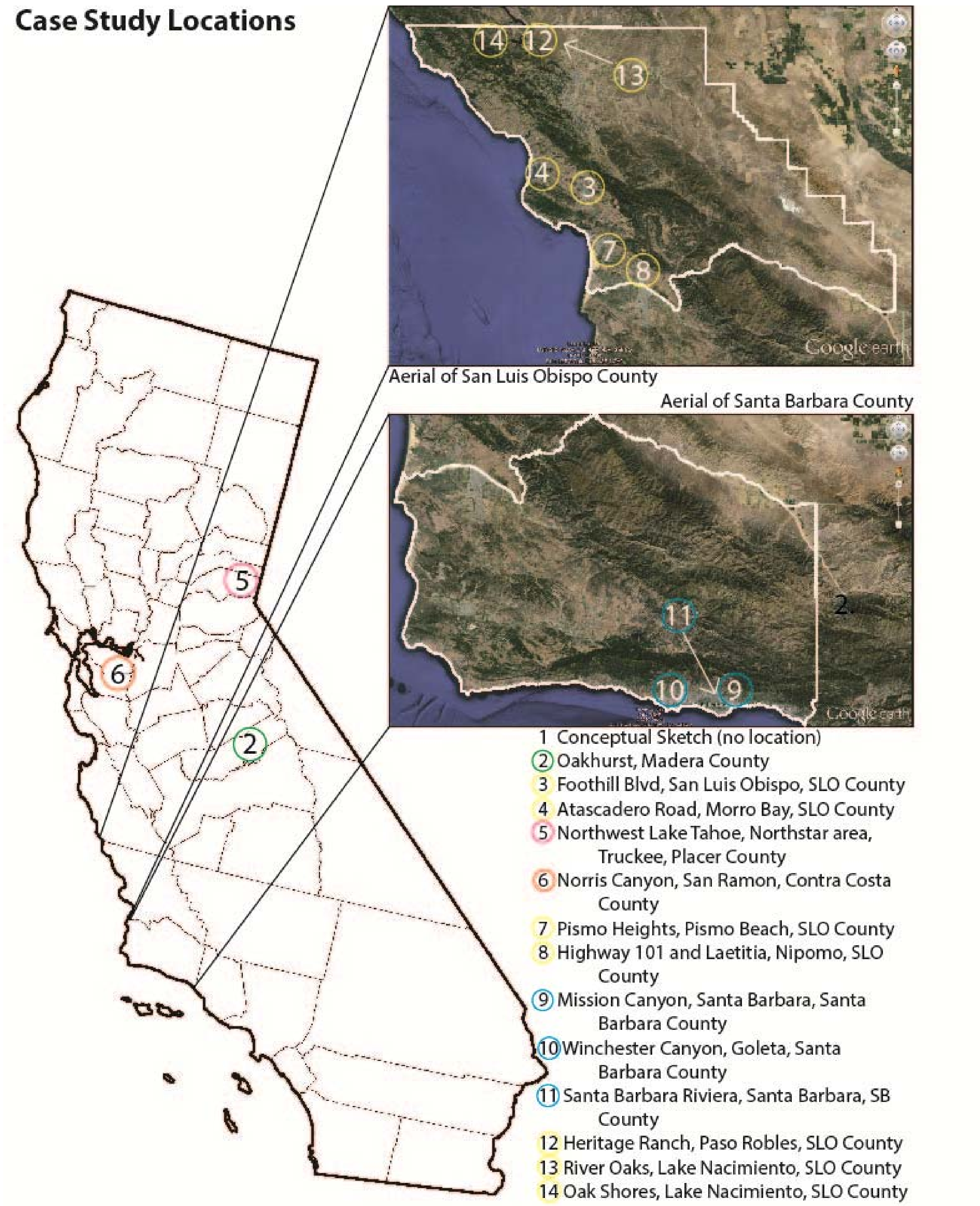
Summary

Number of Segments: 10

Average Network/Facility Operating Speed (MPH): 5.0

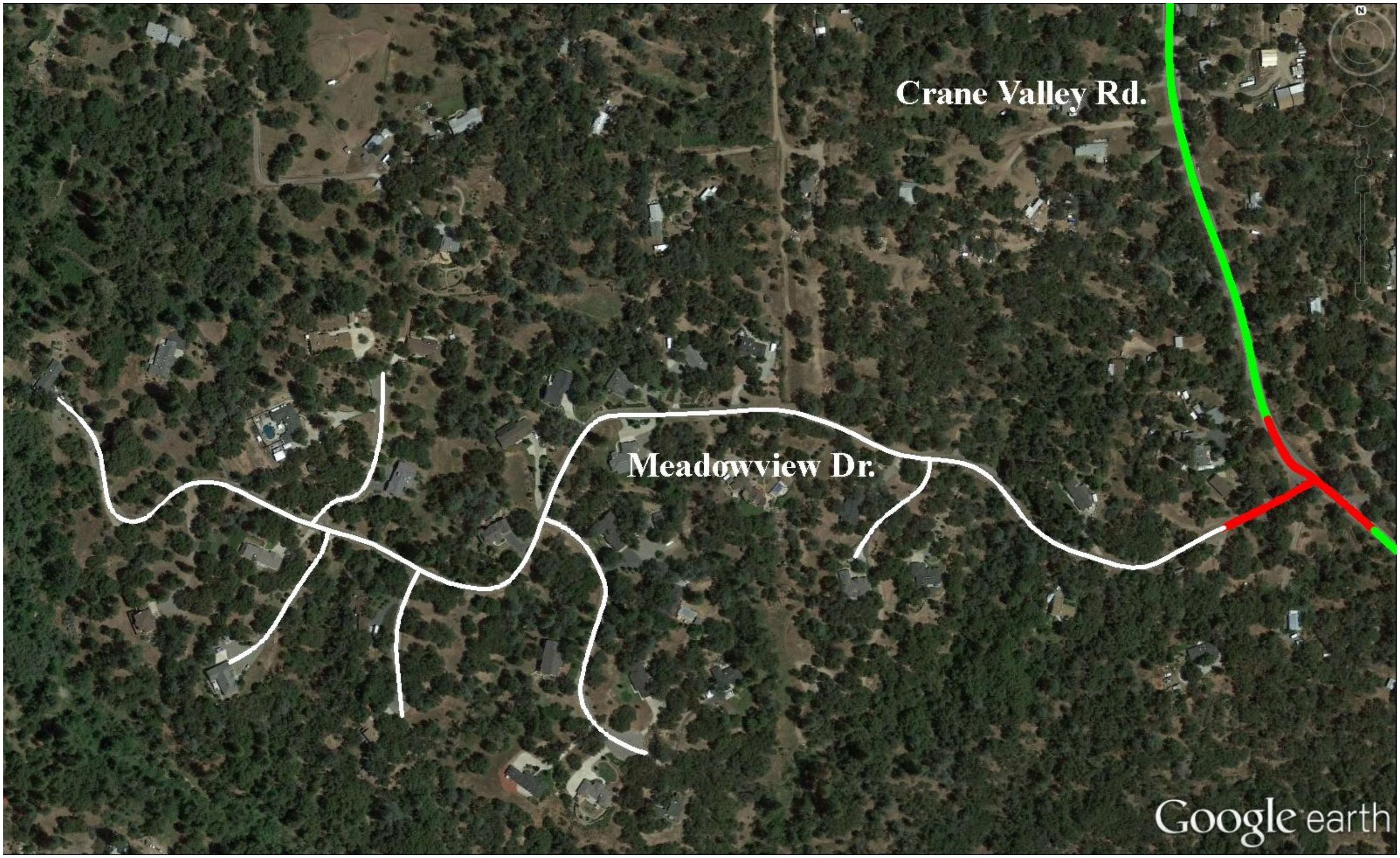
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (*Exhibit 17-11*)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	4	100	25	37.4	2.73	1	1	10	244	7	3.9	5.4
Segment 2	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 3	24	700	25	37.4	19.09	2	1	59	1467	40	20.9	9.2
Segment 4	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 5	16	464	25	37.4	12.65	3	1	39	978	27	14.0	7.1
Segment 6	66	464	25	37.4	12.65	3	1	161	4033	110	97.3	2.5
Segment 7	8	236	25	37.4	6.44	2	1	20	489	13	6.9	6.4
Segment 8	6	228	25	37.4	6.22	2	1	15	367	10	3.8	7.1
Segment 9	56	228	25	37.4	6.22	2	1	137	3422	93	87.1	1.5
Segment 10	8	228	25.0	37.4	6.22	1	1	20	489	13	7.1	8.0

4.0 APPLICATION OF METHODOLOGY BY CASE STUDY

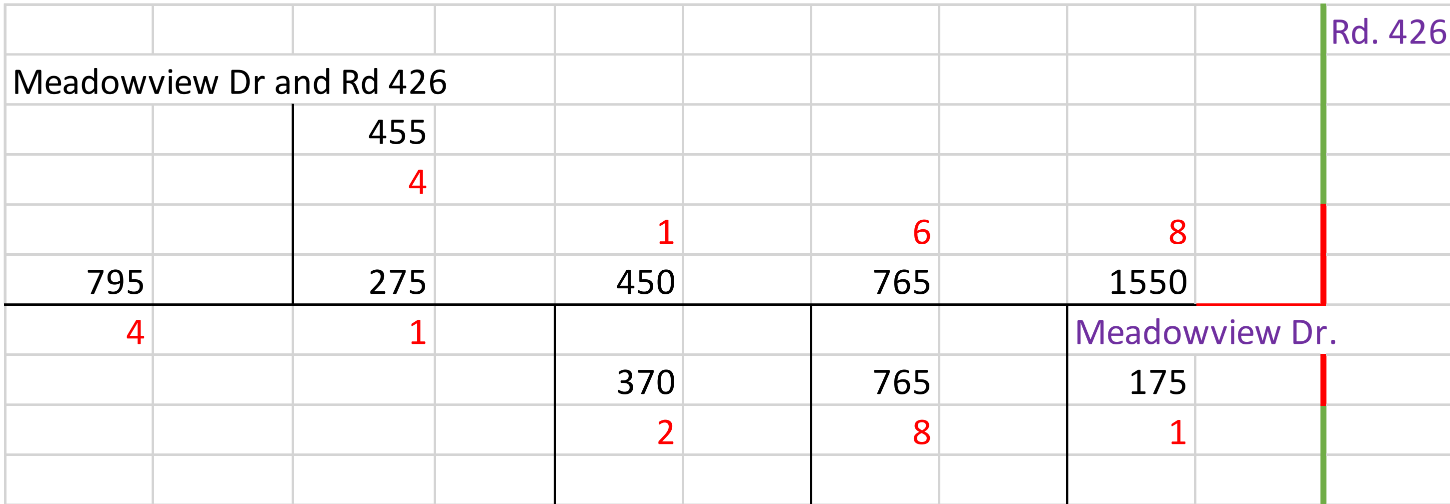


This page intentionally left blank

Oakhurst: Meadowview Dr. and Rd 426

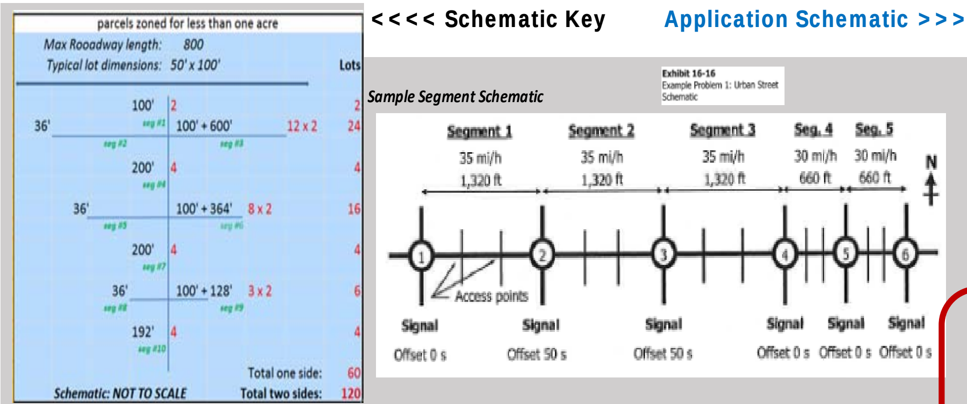


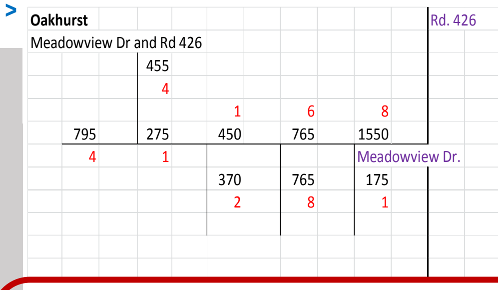
Oakhurst: Meadowview Dr. and Rd 426: Roadway schematic



LEGEND

00	Length of segment (intersection to intersection in feet)
00 (red)	Number of houses on segment
[black line]	Subdivision roadway segment
[red line]	Potential bottleneck upon exit of development
[green line]	Nearby through road





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
105	33	138	86	5.9

Input

Number of Segments: 10

Summary

Average Network/Facility Operating Speed (MPH): 11.7

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	8	1550	25	37.4	42.27	1	1	20	489	13	0.0	21.9
Segment 2	1	175	25	37.4	4.77	2	1	2	61	2	0.0	7.1
Segment 3	6	765	25	37.4	20.86	2	1	15	367	10	0.0	15.9
Segment 4	8	765	25	37.4	20.86	3	1	20	489	13	0.0	13.4
Segment 5	1	450	25	37.4	12.27	3	1	2	61	2	0.0	10.1
Segment 6	2	370	25	37.4	10.09	4	1	5	122	3	0.0	7.4
Segment 7	1	275	25	37.4	7.50	4	1	2	61	2	0.0	6.0
Segment 8	4	455	25	37.4	12.41	5	1	10	244	7	0.0	7.3
Segment 9	4	795	25	37.4	21.68	5	1	10	244	7	0.0	10.5
Segment 10												

Facility	PBFS 47%	LOS D	Longest segment combo? (Y=1)	Longest combo run time (104.6)	Longest combo delay (33.3)
Segment 1	88%	A	1	42.3	13.3
Segment 2	28%	F			
Segment 3	63%	C	1	20.9	10.0
Segment 4	54%	C			
Segment 5	41%	D	1	12.3	1.7
Segment 6	30%	F			
Segment 7	24%	F	1	7.5	1.7
Segment 8	29%	F			
Segment 9	42%	D	1	21.7	6.7
Segment 10					

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

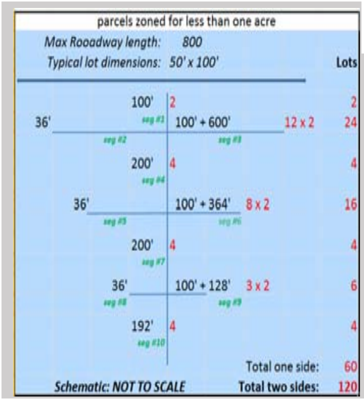
Modeling outcome:
Total clear time is 5.9 minutes

Foothill Blvd and O'Connor Way – Mixed Use

Foothill Blvd and O'Connor Way – Mixed Use: Roadway schematic

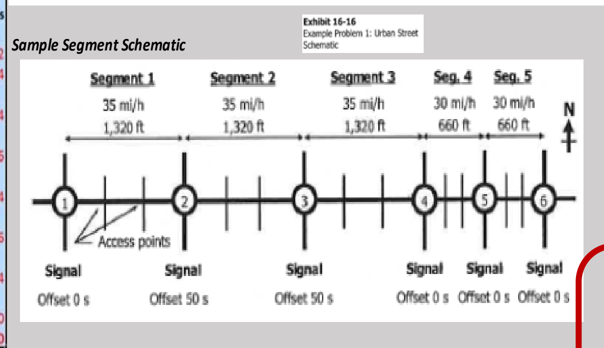
Foothill Blvd and O'Connor Way																				Foothill Blvd.
		1	3		2	2		1	4	2	2		4	5		3	4	1	0	
																Temple Ner Shalom	The Laureate School			
		480	1525		850	1260		650	500	3400	1750		2150	4430		1650	1015	890	1415	
																	Agape Church			
	1030	1215	1335	250	390	410	450	520	1270	1325	375	1300	1320	920	700	385	855	465	1122	
																			O'Connor Way	
				440			1325					1675			2050					
Schools and Churches:				2			3					1			3					
	Agape Church Congregation: 400-440																			
	Temple Ner Shalom:																			
	The Laureate School Population: 120																			

Foothill Blvd and O'Connor Way – Mixed Use: Modeling Summary



<<<< Schematic Key

Application Schematic >>>



Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
367	248	615	466	29.7

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Input

Foothill and O'Connor with Churches and School

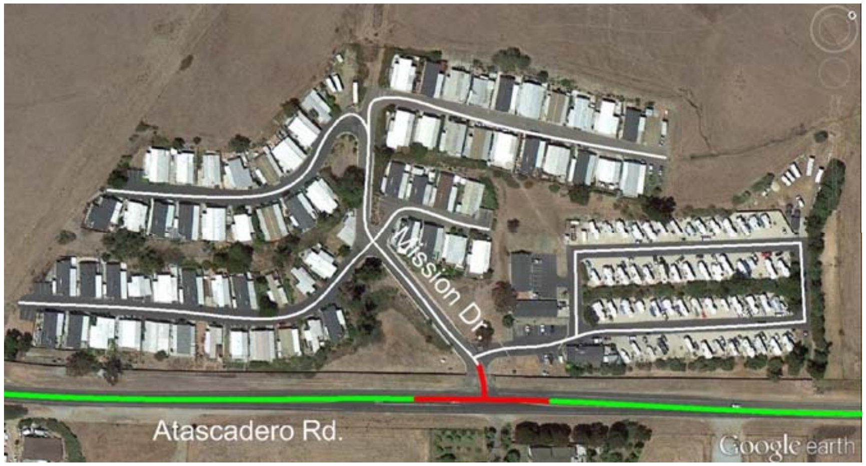
Summary

Number of Segments:	38							Average Network/Facility Operating Speed (MPH):				8.4
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	0	1122	35	42.1	21.86	1	1	0	0	0	0.0	27.5
Segment 2	107	1415	25	37.4	38.59	2	1	263	6566	179	140.5	5.0
Segment 3	0	465	35	42.1	9.06	2	1	0	0	0	0.0	15.1
Segment 4	41	890	25	37.4	24.27	3	1	101	2525	69	44.6	7.0
Segment 5	0	855	35	42.1	16.66	3	1	0	0	0	0.0	16.8
Segment 6	4	1015	25	37.4	27.68	4	1	10	244	7	0.0	13.4
Segment 7	0	385	35	42.1	7.50	4	1	0	0	0	0.0	8.3
Segment 8	3	1650	25	37.4	45.00	5	1	7	183	5	0.0	15.0
Segment 9	0	700	35	42.1	13.64	5	1	0	0	0	0.0	10.9
Segment 10	3	2050	25.0	37.4	55.91	6	1	7	183	5	0.0	15.2

	PBFS	LOS		367.5	247.9
Facility	30%	E	Longest segment combo? (Y=1)	Longest combo run time	Longest combo delay
Segment 1	78%	B	1	21.9	0.0
Segment 2	20%	F	1	38.6	179.1
Segment 3	43%	D	1	9.1	0.0
Segment 4	28%	F	1	24.3	68.9
Segment 5	48%	D	1	16.7	0.0
Segment 6	54%	C			
Segment 7	24%	F	1	7.5	0.0
Segment 8	60%	C			
Segment 9	31%	E	1	13.6	0.0
Segment 10	61%	C			

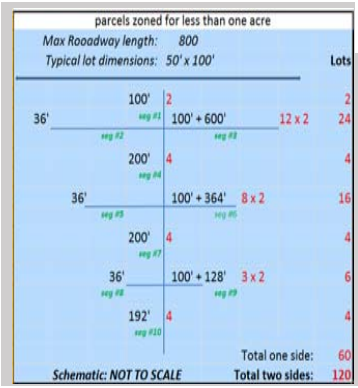
Modeling outcome:
Total clear time is 29.7 minutes

Atascadero Rd and Mission Drive – Mobile Home Park



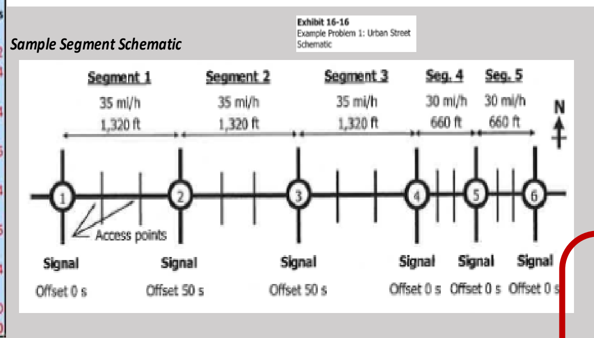
Atascadero Rd and Mission Drive – Mobile Home Park: Roadway schematic

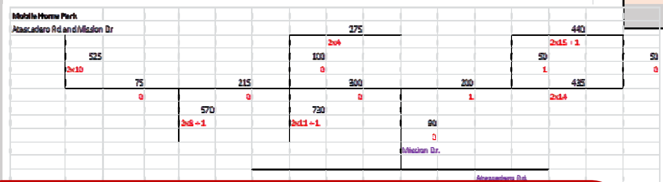
Mobile Home Park																
Atascadero Rd and Mission Dr								275						440		
								2x4						2x15 + 1		
	525						100						50			50
	2x10						0						1			0
		75			215			300			200			435		
		0			0			0			1			2x14		
				570			730									
				2x8 + 1			2x11 + 1			90						
										0						
										Mission Dr.						
												Atascadero Rd.				



<<<< Schematic Key

Application Schematic >>>





Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
33	33	66	315	14.3

Input

Summary

Number of Segments: 15

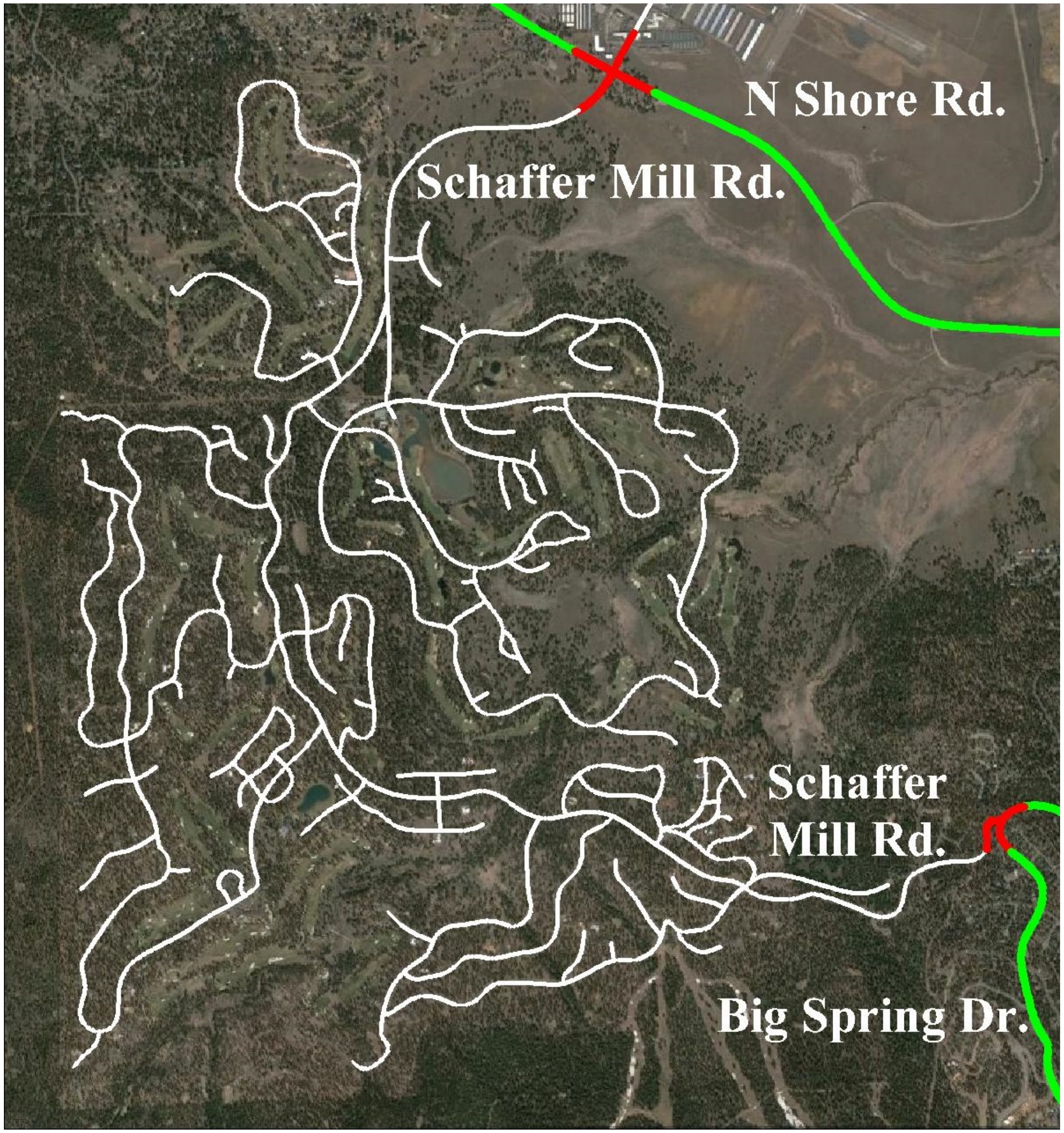
Average Network/Facility Operating Speed (MPH): 5.4

Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (Exhibit 17-11)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	*Segment Volume (pax cars)*	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	*Segment Operation Speed*
Segment 1	0	90	25	37.4	2.45	1	1	0	0	0	0.0	7.3
Segment 2	0	300	25	37.4	8.18	2	1	0	0	0	0.0	10.1
Segment 3	0	100	25	37.4	2.73	3	1	0	0	0	0.0	3.3
Segment 4	8	275	25	37.4	7.50	4	1	20	489	13	5.8	5.0
Segment 5	23	730	25	37.4	19.91	3	1	56	1406	38	18.4	8.8
Segment 6	0	215	25	37.4	5.86	3	1	0	0	0	0.0	6.1
Segment 7	17	570	25	37.4	15.55	4	1	42	1039	28	12.8	7.4
Segment 8	0	75	25	37.4	2.05	4	1	0	0	0	0.0	2.0
Segment 9	20	525	25	37.4	14.32	5	1	49	1222	33	19.0	5.7
Segment 10	1	200	25.0	37.4	5.45	2	1	2	61	2	0.0	7.8

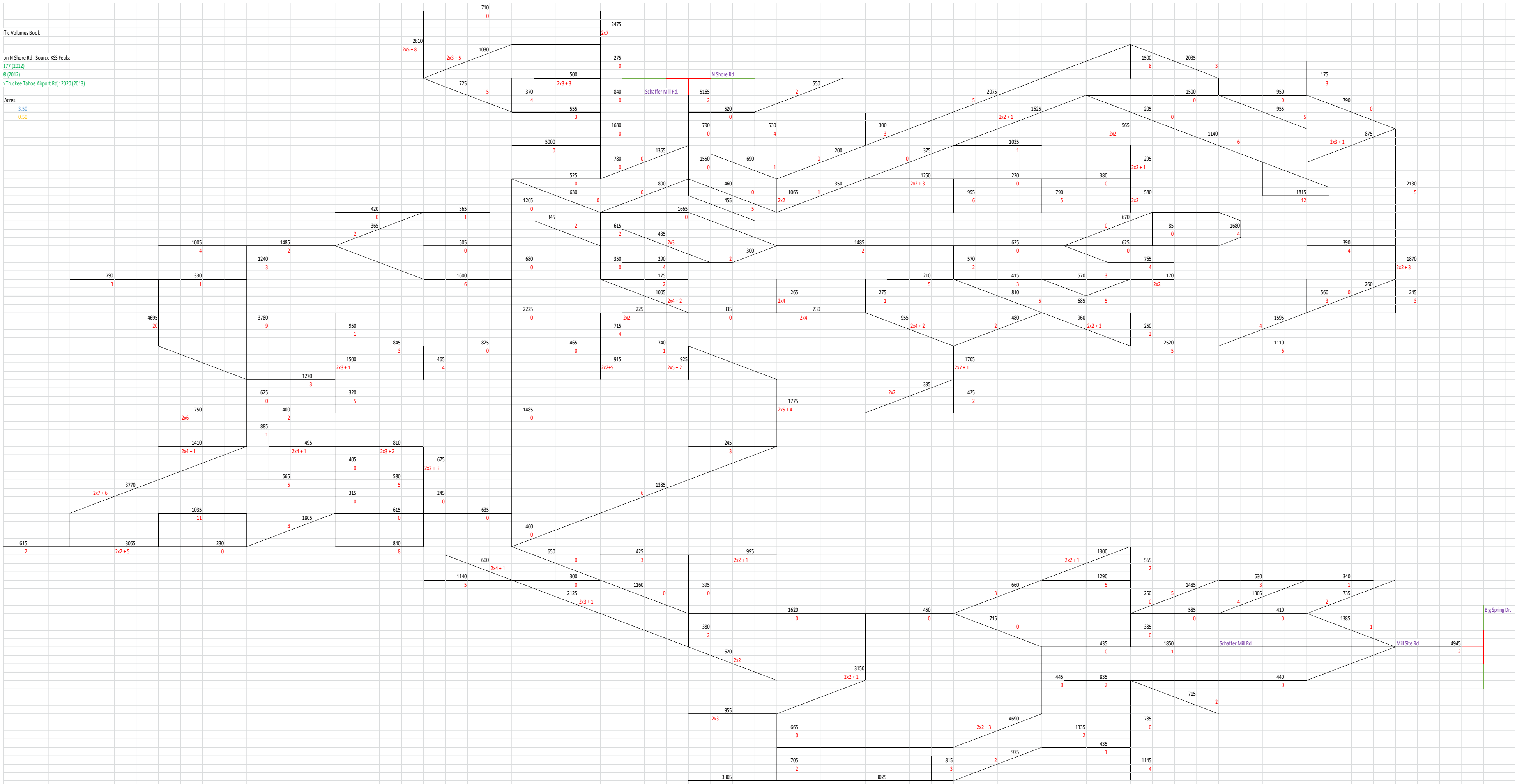
	PBFS	LOS		32.9	33.3
Facility	22%	F	Longest segment combo? (Y=1)	Longest combo run time	Longest combo delay
Segment 1	29%	F	1	2.5	0.0
Segment 2	41%	D	1	8.2	0.0
Segment 3	13%	F			
Segment 4	20%	F			
Segment 5	35%	E			
Segment 6	25%	F	1	5.9	0.0
Segment 7	30%	F			
Segment 8	8%	F	1	2.0	0.0
Segment 9	23%	F	1	14.3	33.3
Segment 10	31%	E			

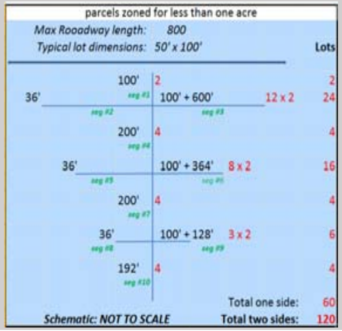
Modeling outcome:
Total clear time is 14.3 minutes

<u>Northwest Lake Tahoe</u>



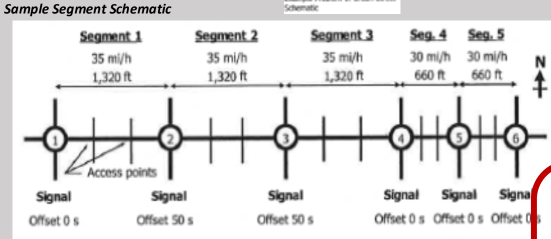
Northwest Lake Tahoe: Roadway schematic



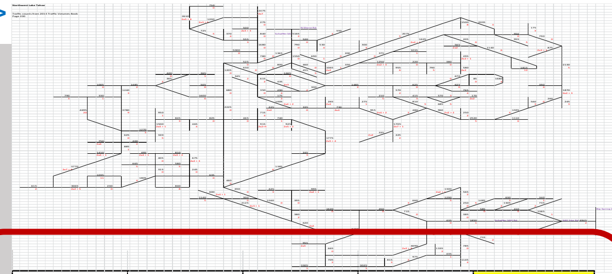


<<<< Schematic Key

Sample Segment Schematic



Application Schematic >>>



Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
730	8	738	1621	79.9

Legend of Cell Colors

- Enter input data
- Calculations -- browse
- References -- Do not touch

Input

Number of Segments: *200*

Summary

Average Network/Facility Operating Speed (MPH): 7.6

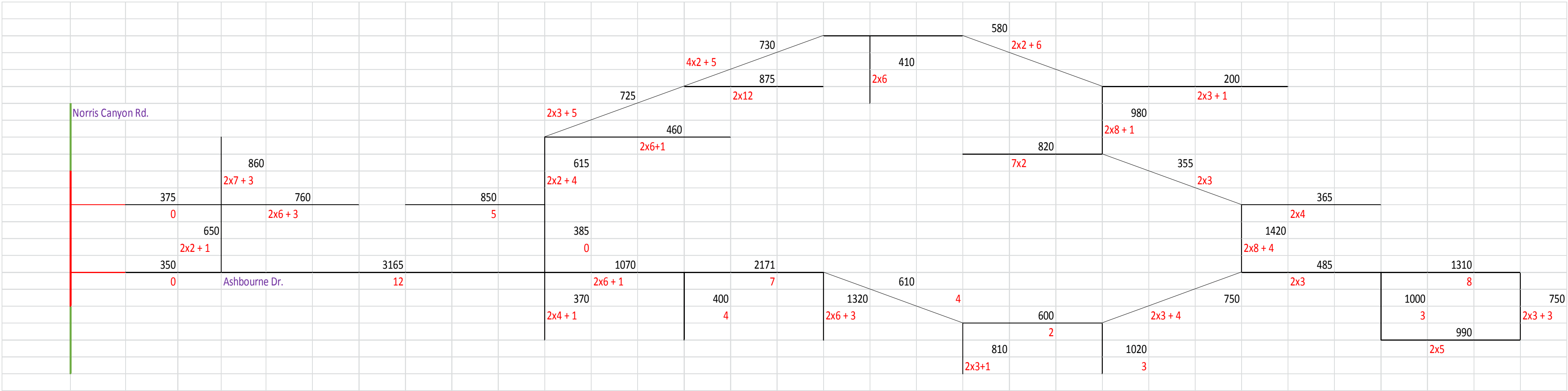
Segment	*Houses on Segment*	*Segment Length (L_i)*	*Segment Speed Limit ($S_{fo,i}$)*	*Speed Constant (Exhibit 17-11)*	*Segment Running Time (t_R) -- (sec)*	*Full Stop Rate (intersections traversed)*	*Segment Directional Lanes*	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	*Segment Operation Speed*
Segment 1	2	5165	25	37.4	140.86	1	1	5	122	3	0.0	24.0
Segment 2	0	520	25	37.4	14.18	2	1	0	0	0	0.0	13.5
Segment 3	2	5165	25	37.4	140.86	3	1	5	122	3	0.0	22.2
Segment 4	2	550	25	37.4	15.00	3	1	5	122	3	0.0	11.4
Segment 5	0	790	25	37.4	21.55	2	1	0	0	0	0.0	16.1
Segment 6	0	1550	25	37.4	42.27	3	1	0	0	0	0.0	17.5
Segment 7	0	1365	25	37.4	37.23	3	1	0	0	0	0.0	16.9
Segment 8	0	525	25	37.4	14.32	3	1	0	0	0	0.0	11.1
Segment 9	0	780	25	37.4	21.27	4	1	0	0	0	0.0	11.7
Segment 10	0	5000	25.0	37.4	136.36	5	1	0	0	0	0.0	20.5
Segment 11	0	1680	25.0	37.4	45.82	5	1	0	0	0	0.0	15.1
Segment 12	3	555	25.0	37.4	15.14	6	1	7	183	5	0.0	7.4
Segment 13	4	370	25.0	37.4	10.09	7	1	10	244	7	0.0	4.8

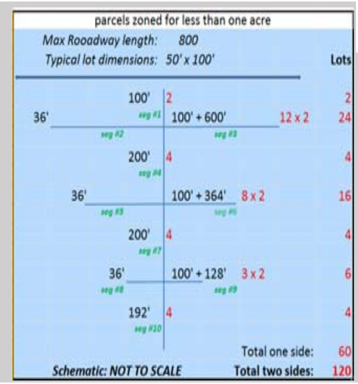
Facility	PBFS 30%	LOS E	Longest segment combo? (Y=1)	Longest combo run time 729.7	Longest combo delay 8.3
Segment 1	96%	A	1	140.9	3.3
Segment 2	54%	C			
Segment 3	89%	A			
Segment 4	45%	D			
Segment 5	64%	C	1	21.5	0.0
Segment 6	70%	B	1	42.3	0.0
Segment 7	67%	B			
Segment 8	44%	D	1	14.3	0.0
Segment 9	47%	D			
Segment 10	82%	B			
Segment 11	60%	C			
Segment 12	30%	F			
Segment 13	19%	F			

Modeling outcome:
Total clear time is 79.9 minutes

Norris Canyon Estates

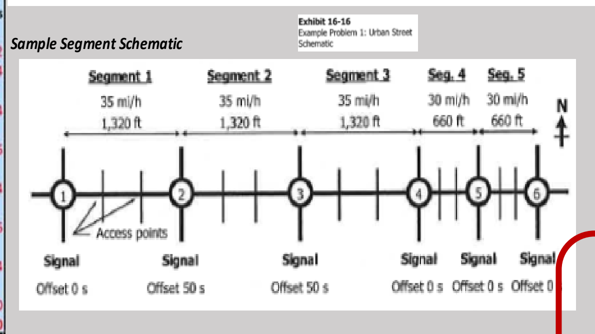
Norris Canyon Estate: Roadway schematic

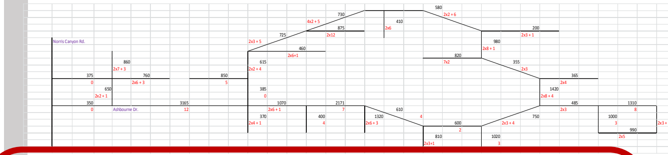




<<<< Schematic Key

Application Schematic >>>





Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
323	200	523	799	42.1

Input

Number of Segments: 38

Summary

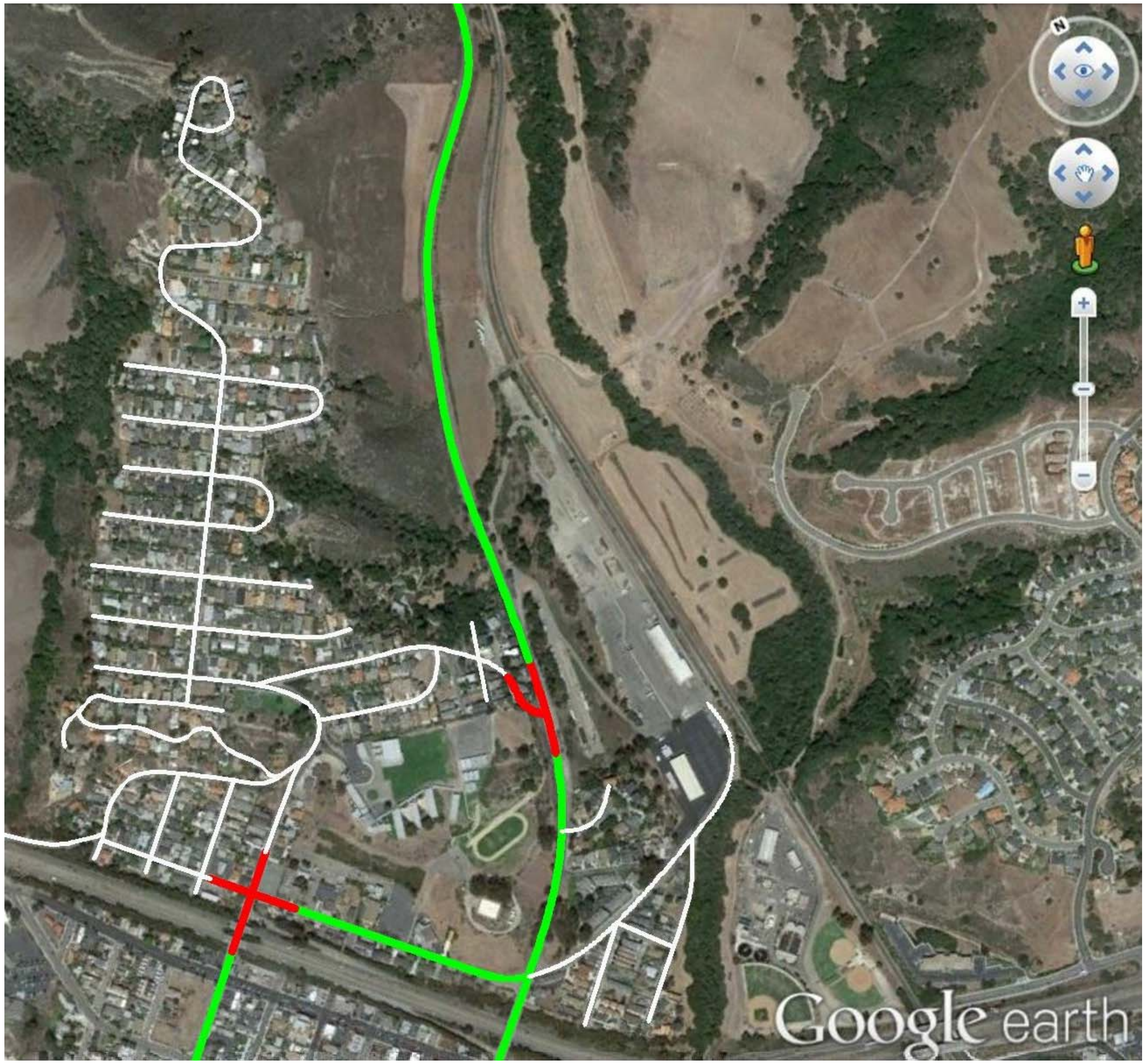
Average Network/Facility Operating Speed (MPH): 9.0

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	0	375	25	37.4	10.23	1	1	0	0	0	0.0	15.8
Segment 2	17	860	25	37.4	23.45	2	1	42	1039	28	4.9	14.5
Segment 3	15	760	25	37.4	20.73	2	1	37	917	25	4.3	14.0
Segment 4	5	650	25	37.4	17.73	2	1	12	306	8	0.0	14.9
Segment 5	0	350	25	37.4	9.55	1	1	0	0	0	0.0	15.4
Segment 6	12	3165	25	37.4	86.32	2	1	29	733	20	0.0	21.9
Segment 7	0	385	25	37.4	10.50	3	1	0	0	0	0.0	9.2
Segment 8	5	850	25	37.4	23.18	4	1	12	306	8	0.0	12.3
Segment 9	8	615	25	37.4	16.77	4	1	20	489	13	0.0	10.3
Segment 10	13	460	25.0	37.4	12.55	5	1	32	794	22	9.1	6.1

Facility	PBFS 36%	LOS E	Longest segment combo? (Y=1)	Longest combo run time (323.2)	Longest combo delay (200.0)
Segment 1	63%	C			
Segment 2	58%	C			
Segment 3	56%	C			
Segment 4	60%	C			
Segment 5	61%	C	1	9.5	0.0
Segment 6	88%	A	1	86.3	20.0
Segment 7	37%	E	1	10.5	0.0
Segment 8	49%	D			
Segment 9	41%	D	1	16.8	13.3
Segment 10	24%	F			

Modeling outcome:
Total clear time is 42.1 minutes

Pismo Heights



Pismo Heights: Roadway schematic

Pismo Heights

Churches and school:

First Church - Christ Scientist: 8-12
St. Pauls Catholic Church: 700-800

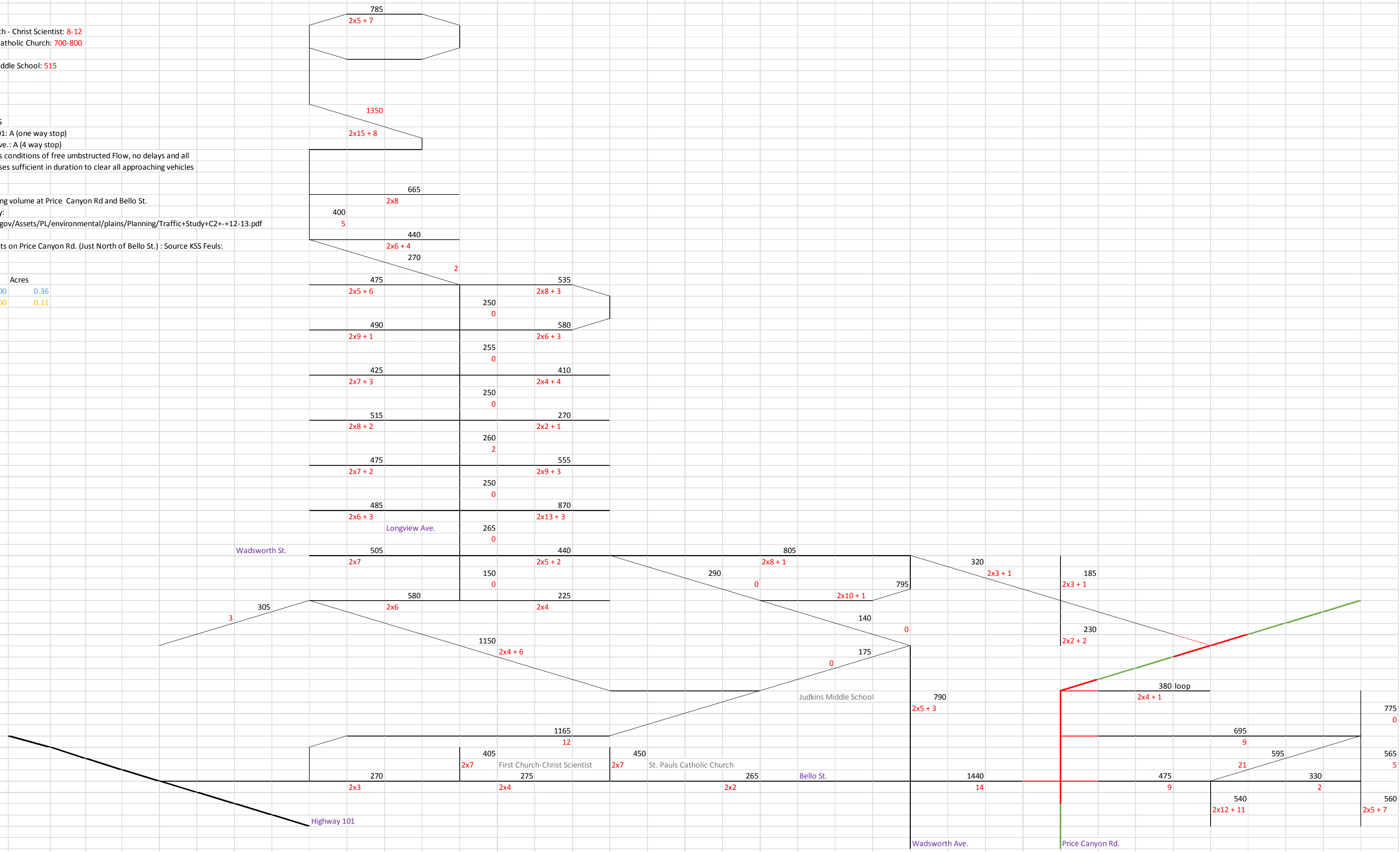
Judkins Middle School: 515

Peak hour intersection LOS
Bello St./Bay St. and US 101: A (one way stop)
Bello St and Wadsworth Ave.: A (4 way stop)
A indicates conditions of free umbstructed Flow, no delays and all signal phases sufficient in duration to clear all approaching vehicles

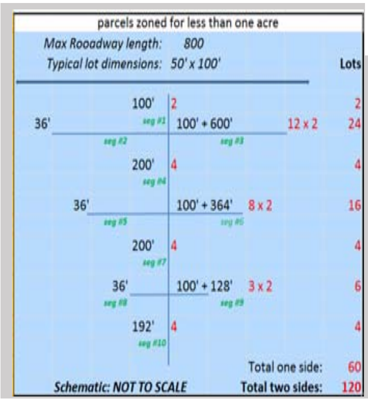
Peak hour traffic and turning volume at Price Canyon Rd and Bello St.
See PDF from Impact Study:
http://www.slocounty.ca.gov/Assets/PL/environmental/plains/Planning/Traffic+Study+C2+-+12-13.pdf

Average Daily Traffic Counts on Price Canyon Rd. (Just North of Bello St.) : Source KSS Feuls:
9854 (2012)

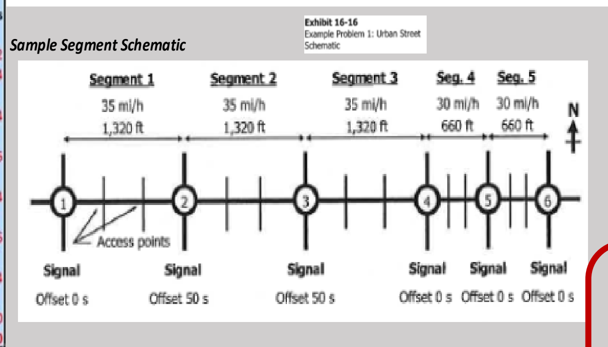
	Sq. Ft.	Acres
Largest Lot:	15,700	0.36
Smallest Lot:	5,000	0.11



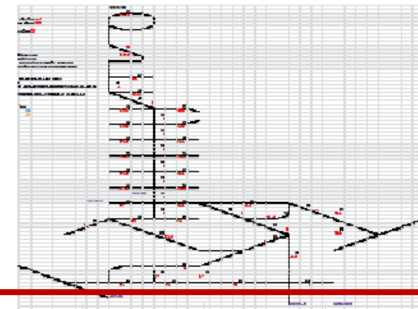
Pismo Heights: Modeling Summary



<<<< Schematic Key



Application Schematic >>>



Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
217	200	417	1149	54.9

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Input

Pismo Heights Homes Only

Summary

Number of Segments: 45

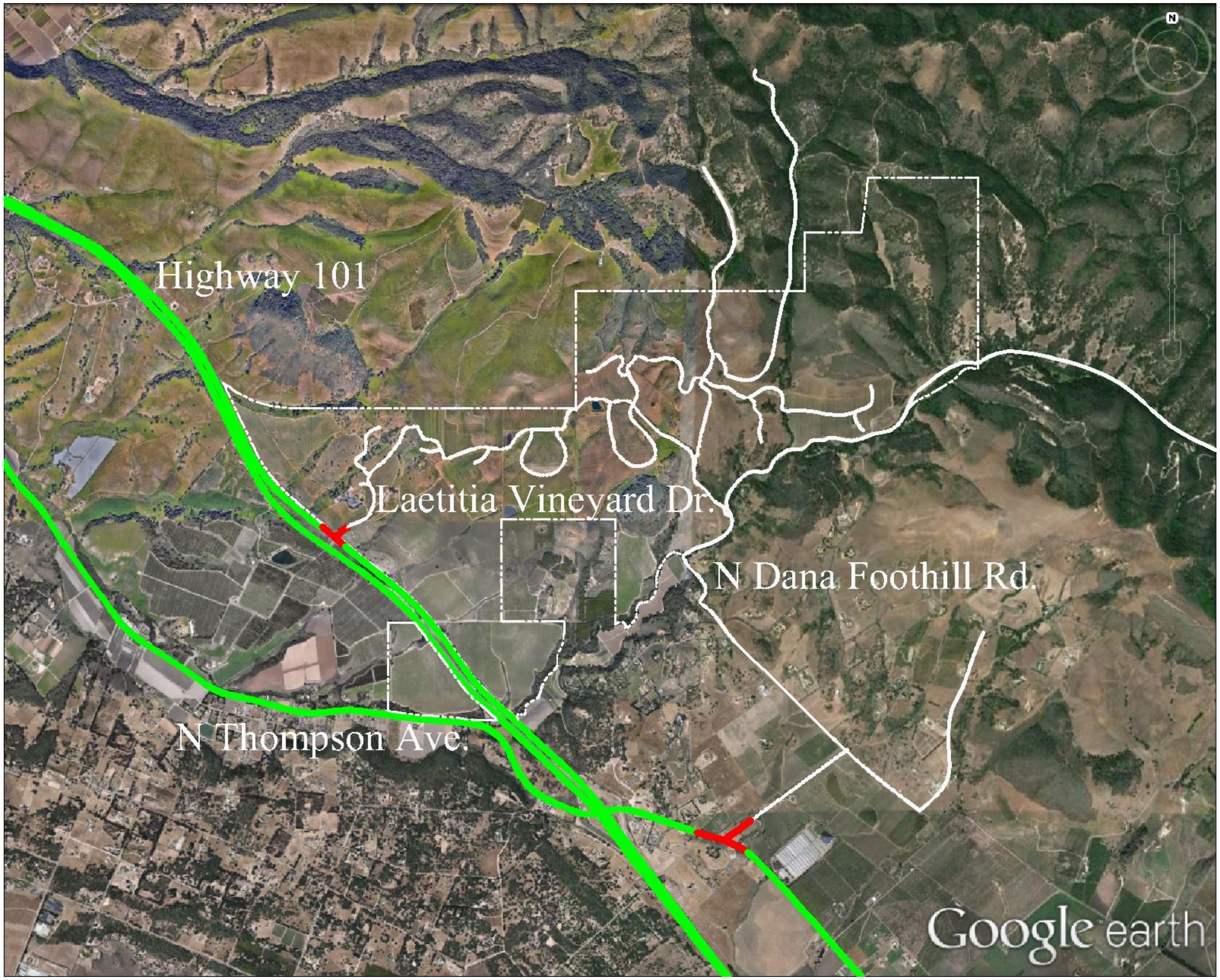
Average Network/Facility Operating Speed (MPH): 6.0

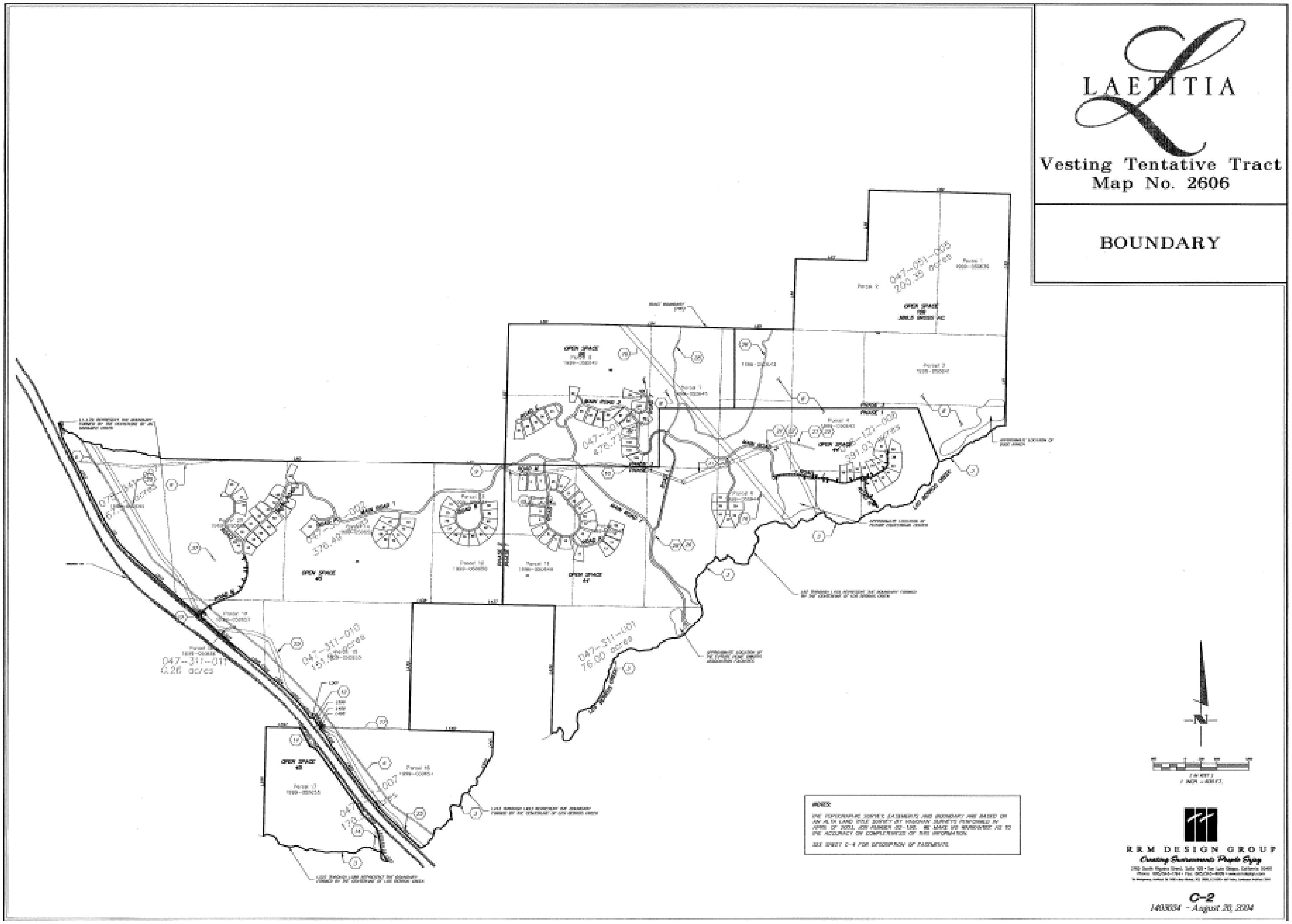
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	14	1440	25	37.4	39.27	1	1	34	856	23	0.0	21.7
Segment 2	4	265	25	37.4	7.23	1	1	10	244	7	0.0	13.7
Segment 3	14	450	25	37.4	12.27	2	1	34	856	23	11.1	8.7
Segment 4	8	275	25	37.4	7.50	2	1	20	489	13	5.8	7.4
Segment 5	14	405	25	37.4	11.05	3	1	34	856	23	12.3	6.7
Segment 6	6	270	25	37.4	7.36	3	1	15	367	10	2.6	6.6
Segment 7	12	1165	25	37.4	31.77	3	1	29	733	20	0.0	16.0
Segment 8	0	175	25	37.4	4.77	2	1	0	0	0	0.0	7.1
Segment 9	14	1150	25	37.4	31.36	3	1	34	856	23	0.0	15.9
Segment 10	3	305	25.0	37.4	8.32	4	1	7	183	5	0.0	6.4

Facility	PBFS 24%	LOS F	Longest segment combo? (Y=1)	Longest combo run time 216.5	Longest combo delay 200.0
Segment 1	87%	A			
Segment 2	55%	C	1	7.2	6.7
Segment 3	35%	E			
Segment 4	30%	F	1	7.5	13.3
Segment 5	27%	F			
Segment 6	26%	F	1	7.4	10.0
Segment 7	64%	C	1	31.8	20.0
Segment 8	28%	F			
Segment 9	64%	C	1	31.4	23.3
Segment 10	26%	F			

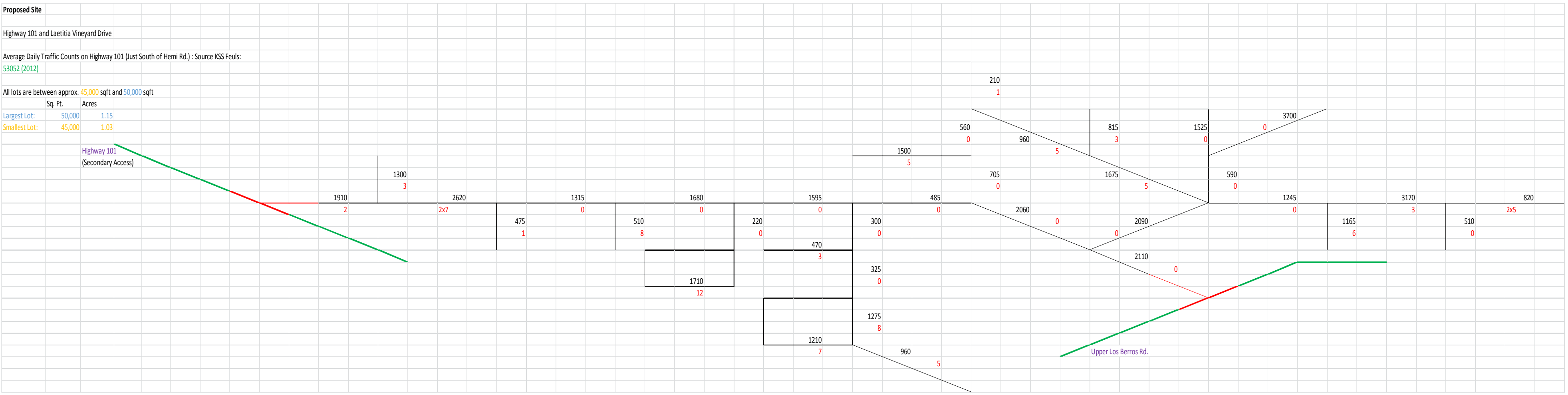
Modeling outcome:
Total clear time is 54.9 minutes

Proposed Development: Laetitia Vineyard Drive

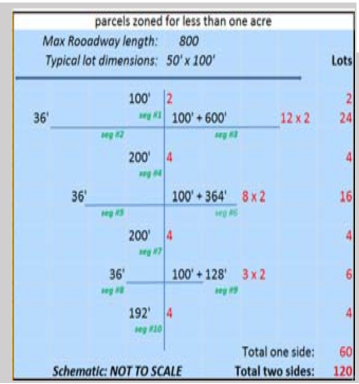



LAETITIA
Vesting Tentative Tract Map No. 2606
BOUNDARY
047-051-005
203.35 acres
047-311-010
047-311-011
0.26 acres
047-311-001
76.00 acres
OPEN SPACE
RRM DESIGN GROUP
C-2
1403034 - August 20, 2004

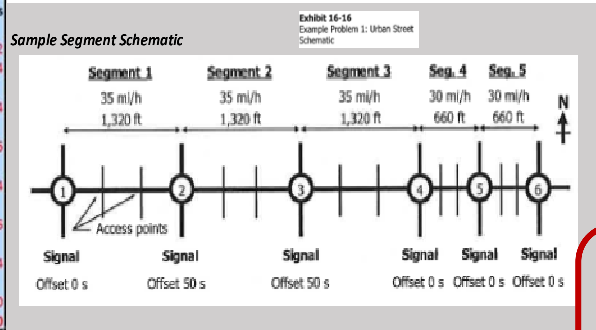
Proposed Development: Laetitia Vineyard Drive: Roadway schematic



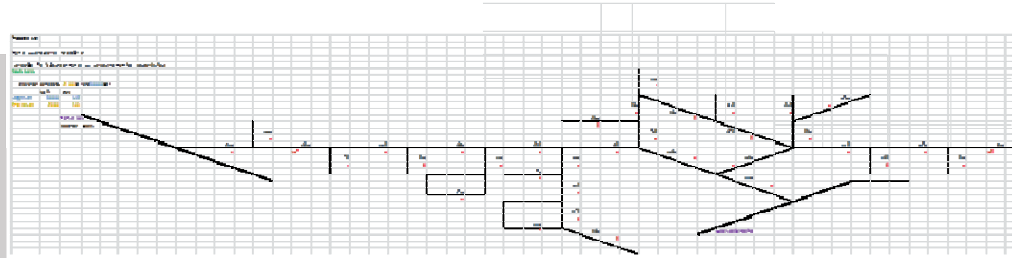
Proposed Development: Laetitia Vineyard Drive: Modeling Summary



<<<< Schematic Key



Application Schematic >>>



Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
376	27	402	247	17.0

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Input

Number of Segments: 36

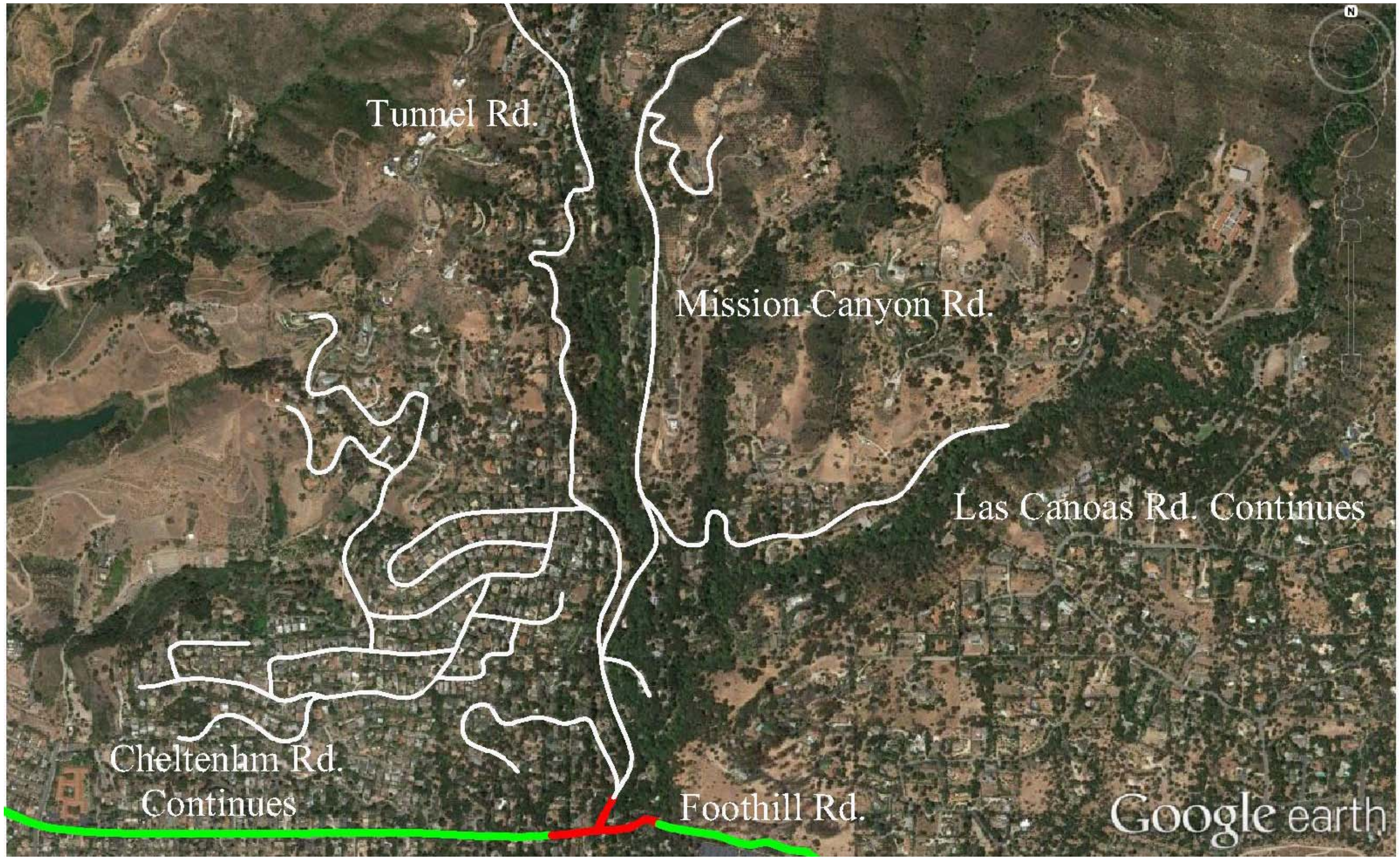
Summary

Average Network/Facility Operating Speed (MPH): 14.9

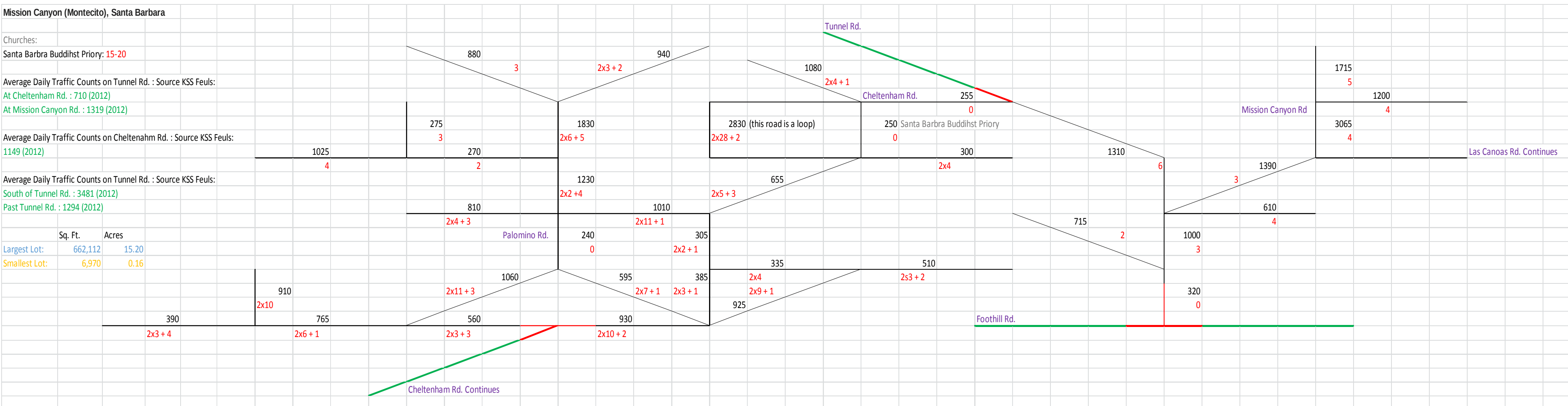
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed	Facility	PBFS 60%	LOS C	Longest segment combo? (Y=1)	375.7 Longest combo run time	26.7 Longest combo delay
Segment 1	0	2110	25	37.4	57.55	1	1	0	0	0	0.0	22.6	Segment 1	91%	A	1	57.5	0.0
Segment 2	0	2090	25	37.4	57.00	2	1	0	0	0	0.0	20.7	Segment 2	83%	B			
Segment 3	0	2060	25	37.4	56.18	2	1	0	0	0	0.0	20.6	Segment 3	82%	B	1	56.2	0.0
Segment 4	0	485	25	37.4	13.23	3	1	0	0	0	0.0	10.6	Segment 4	42%	D	1	13.2	0.0
Segment 5	0	300	25	37.4	8.18	4	1	0	0	0	0.0	6.4	Segment 5	25%	F			
Segment 6	3	470	25	37.4	12.82	5	1	7	183	5	0.0	7.5	Segment 6	30%	F			
Segment 7	0	325	25	37.4	8.86	5	1	0	0	0	0.0	5.7	Segment 7	23%	F			
Segment 8	8	1275	25	37.4	34.77	6	1	20	489	13	0.0	12.3	Segment 8	49%	D			
Segment 9	7	1210	25	37.4	33.00	6	1	17	428	12	0.0	12.0	Segment 9	48%	D			
Segment 10	5	960	25.0	37.4	26.18	7	1	12	306	8	0.0	9.6	Segment 10	38%	E			

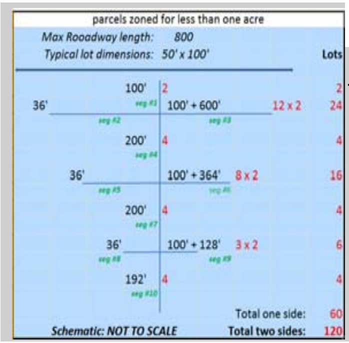
Modeling outcome:
Total clear time is 17.0 minutes

Mission Canyon

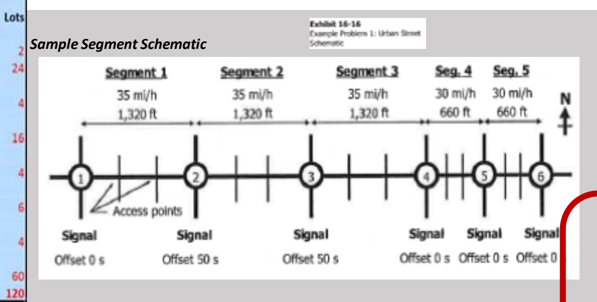


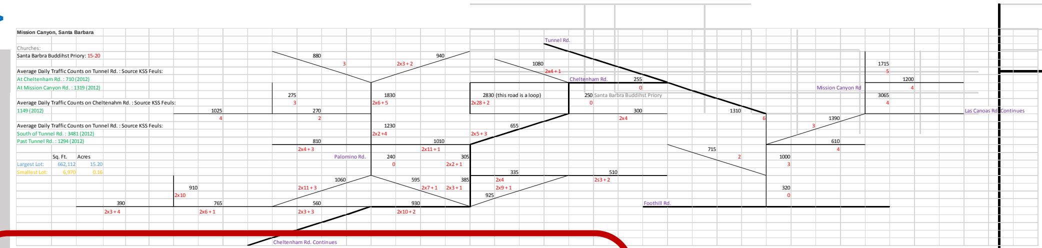
Mission Canyon: Roadway schematic





<<<< Schematic Key **Application Schematic >>>**





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
190	23	214	853	39.2

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Input

Number of Segments: 38

Summary

Average Network/Facility Operating Speed (MPH): 12.8

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	9	560	25	37.4	15.27	1	1	22	550	15	0.0	17.9
Segment 2	13	765	25	37.4	20.86	2	1	32	794	22	0.8	15.5
Segment 3	20	910	25	37.4	24.82	3	1	49	1222	33	8.5	12.1
Segment 4	10	390	25	37.4	10.64	3	1	24	611	17	6.0	7.7
Segment 5	25	1060	25	37.4	28.91	2	1	61	1528	42	12.8	13.5
Segment 6	15	595	25	37.4	16.23	2	1	37	917	25	8.8	11.0
Segment 7	0	240	25	37.4	6.55	3	1	0	0	0	0.0	6.7
Segment 8	11	810	25	37.4	22.09	4	1	27	672	18	0.0	12.0
Segment 9	23	1010	25	37.4	27.55	4	1	56	1406	38	10.8	11.0
Segment 10	8	1230	25.0	37.4	33.55	3	1	20	489	13	0.0	16.3

Facility	PBFS 51%	LOS C	Longest segment combo? (Y=1)	Longest combo run time 190.2	Longest combo delay 23.3
Segment 1	72%	B			
Segment 2	62%	C			
Segment 3	48%	D			
Segment 4	31%	E			
Segment 5	54%	C			
Segment 6	44%	D			
Segment 7	27%	F			
Segment 8	48%	D			
Segment 9	44%	D			
Segment 10	65%	C			

Modeling outcome:
Total clear time is 39.2 minutes

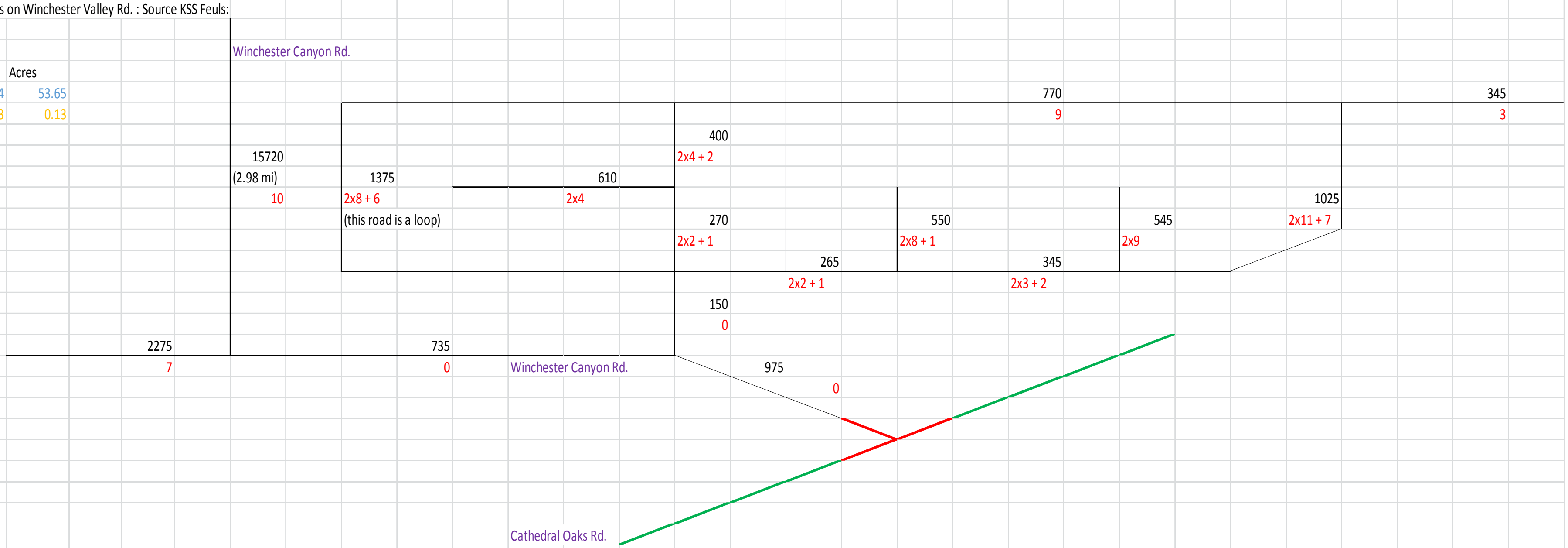
Winchester Canyon

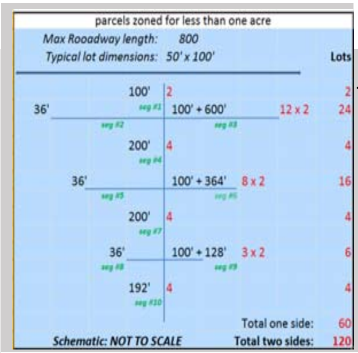
Winchester Canyon: Roadway schematic

Winchester Canyon Rd. and Cathedral Oaks Rd.

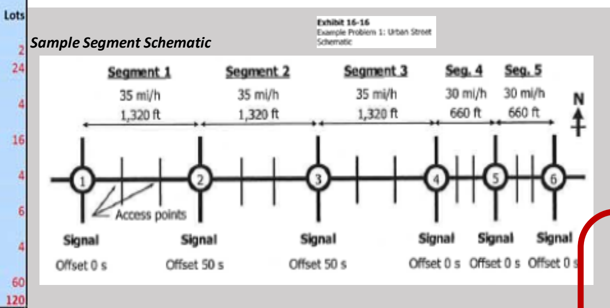
Average Daily Traffic Counts on Winchester Valley Rd. : Source KSS Feuls:
1042 (2000)

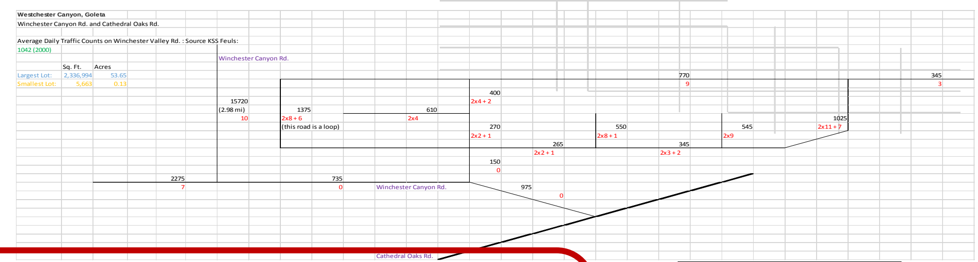
	Sq. Ft.	Acres
Largest Lot:	2,336,994	53.65
Smallest Lot:	5,663	0.13





<<<< Schematic Key **Application Schematic >>>**





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
475	17	492	369	23.6

Legend of Cell Colors

- Enter input data
- Calculations -- browse
- References -- Do not touch

Input

Summary

Number of Segments: 17

Average Network/Facility Operating Speed (MPH): 16.0

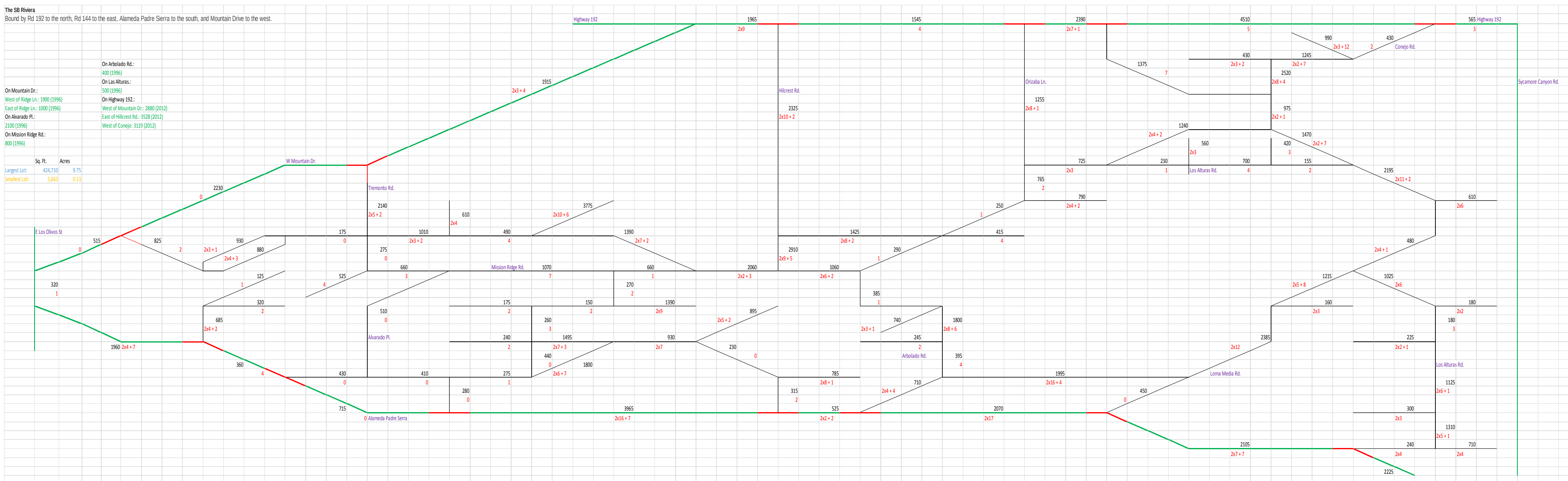
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	0	975	25	37.4	26.59	1	1	0	0	0	0.0	20.4
Segment 2	0	735	25	37.4	20.05	2	1	0	0	0	0.0	15.6
Segment 3	7	2275	25	37.4	62.05	3	1	17	428	12	0.0	19.4
Segment 4	10	15720	25	37.4	428.73	3	1	24	611	17	0.0	24.0
Segment 5	0	150	25	37.4	4.09	2	1	0	0	0	0.0	6.4
Segment 6	22	1375	25	37.4	37.50	3	1	54	1344	37	0.0	16.9
Segment 7	5	270	25	37.4	7.36	3	1	12	306	8	1.0	7.0
Segment 8	8	610	25	37.4	16.64	4	1	20	489	13	0.0	10.2
Segment 9	10	400	25	37.4	10.91	4	1	24	611	17	5.8	6.7
Segment 10	9	700	25.0	37.4	19.09	5	1	22	550	15	0.0	9.7

	PBFS	LOS		475.4	16.7
Facility	64%	C	Longest segment combo? (Y=1)	Longest combo run time	Longest combo delay
Segment 1	82%	B	1	26.6	0.0
Segment 2	63%	C	1	20.0	0.0
Segment 3	78%	B			
Segment 4	96%	A	1	428.7	16.7
Segment 5	25%	F			
Segment 6	68%	B			
Segment 7	28%	F			
Segment 8	41%	D			
Segment 9	27%	F			
Segment 10	39%	E			

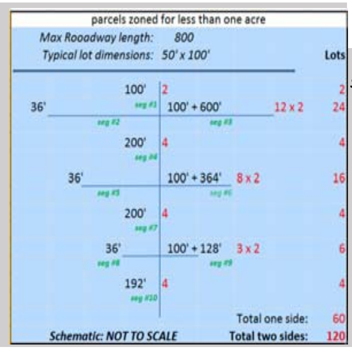
Modeling outcome:
Total clear time is 23.6 minutes

The Santa Barbara Riviera

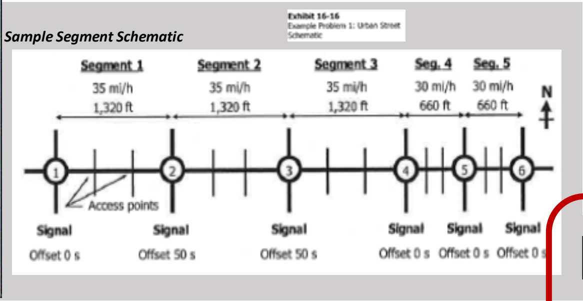
The Santa Barbara Riviera: Roadway schematic

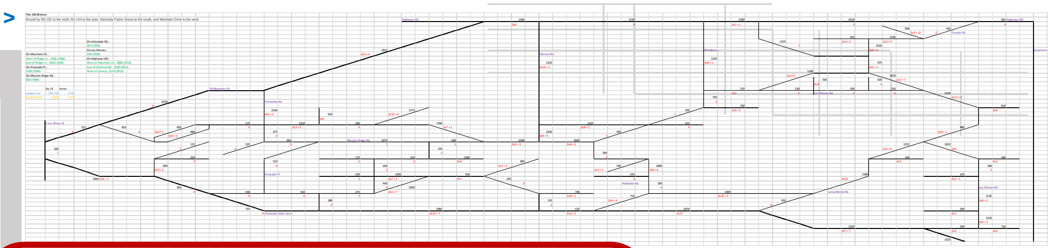


The Santa Barbara Riviera: Modeling Summary



<<<< Schematic Key Application Schematic >>>





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
340	0	340	848	41.1

Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Input

Summary

Number of Segments: 90

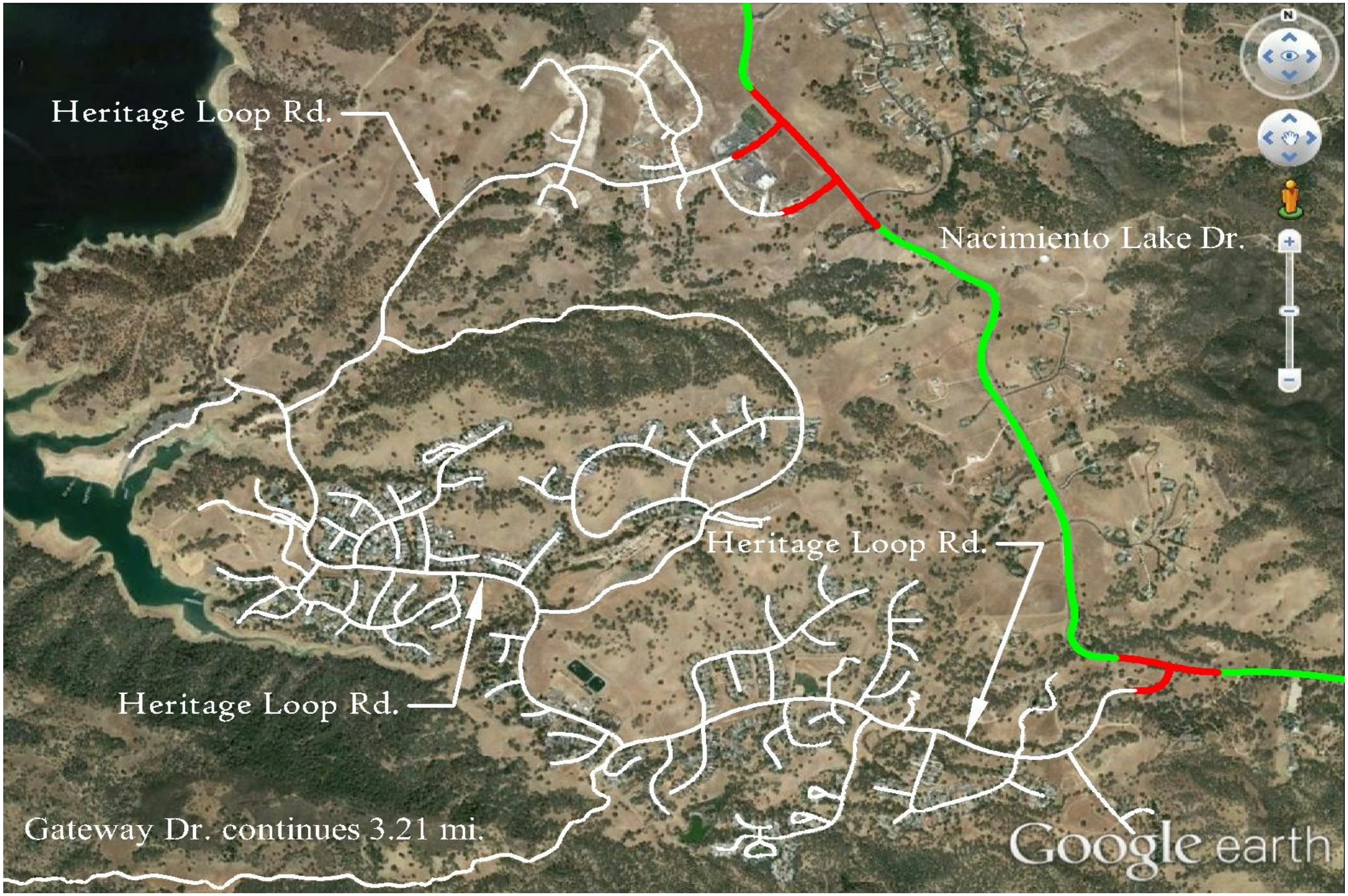
Average Network/Facility Operating Speed (MPH): 14.2

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (*Exhibit 17-11*)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	2	430	25	37.4	11.73	1	1	5	122	3	0.0	16.5
Segment 2	18	990	25	37.4	27.00	2	1	44	1100	30	3.0	16.1
Segment 3	11	1245	25	37.4	33.95	2	1	27	672	18	0.0	18.5
Segment 4	8	430	25	37.4	11.73	3	1	20	489	13	1.6	9.4
Segment 5	20	2520	25	37.4	68.73	2	1	49	1222	33	0.0	21.3
Segment 6	7	1375	25	37.4	37.50	1	1	17	428	12	0.0	21.6
Segment 7	5	975	25	37.4	26.59	2	1	12	306	8	0.0	17.2
Segment 8	10	1240	25	37.4	33.82	3	1	24	611	17	0.0	16.3
Segment 9	11	470	25	37.4	12.82	3	1	27	672	18	5.5	8.8
Segment 10	24	2195	25.0	37.4	59.86	4	1	59	1467	40	0.0	17.8

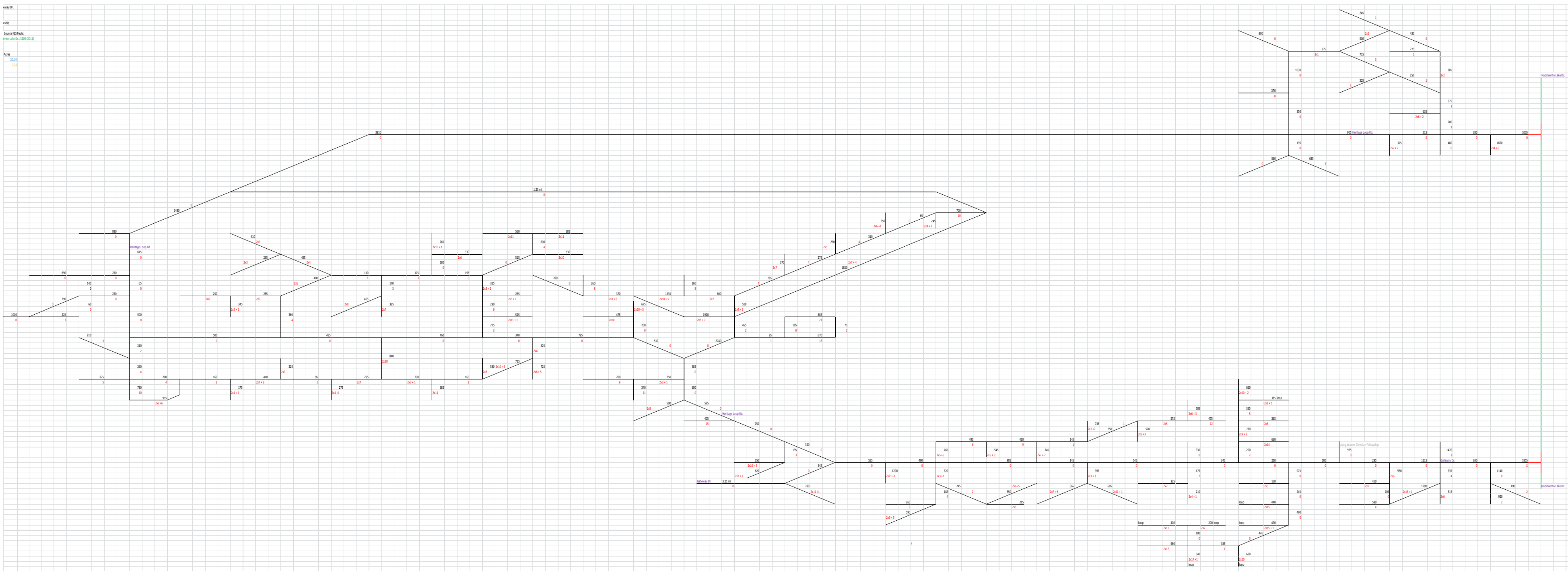
Facility	PBFS 57%	LOS C	Longest segment combo? (Y=1)	Longest combo run time 339.8	Longest combo delay 0.0
Segment 1	66%	C			
Segment 2	64%	C			
Segment 3	74%	B			
Segment 4	37%	E			
Segment 5	85%	A			
Segment 6	86%	A			
Segment 7	69%	B			
Segment 8	65%	C			
Segment 9	35%	E			
Segment 10	71%	B			

Modeling outcome:
Total clear time is 41.1 minutes

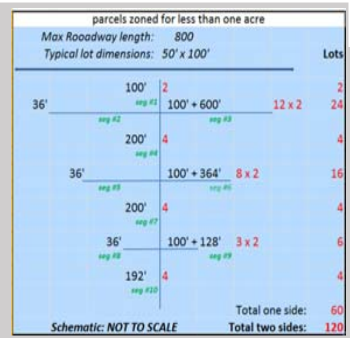
Heritage Ranch (Western and Eastern Entrances)



Heritage Ranch: Roadway schematic



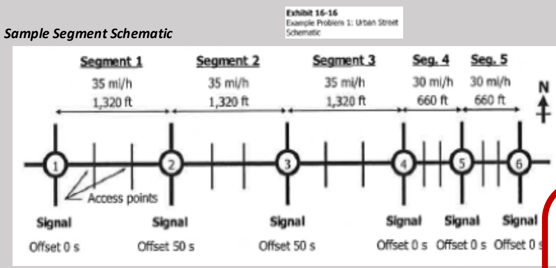
Heritage Ranch – Western Entrance: Modeling Summary

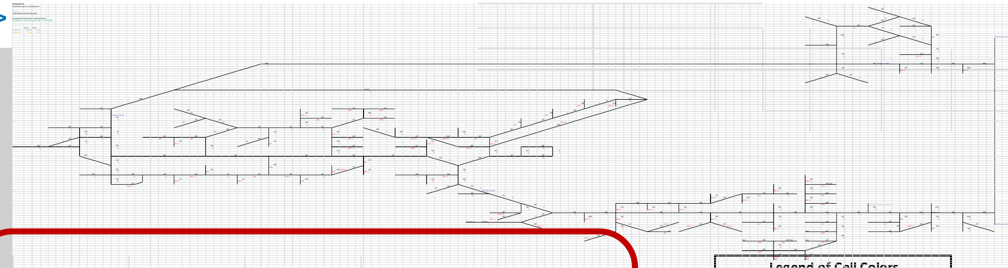


< < < < Schematic Key

Application Schematic > > >

Sample Segment Schematic





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
255	0	255	1435	64.1

Legend of Cell Colors
- Enter input data
- Calculations -- browse
- References -- Do not touch

Input

Summary

Number of Segments: 100

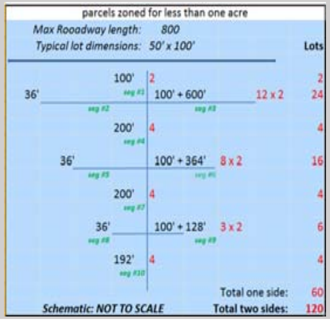
Average Network/Facility Operating Speed (MPH): 4.0

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	0	1005	25	37.4	27.41	1	1	0	0	0	0.0	20.5
Segment 2	14	1620	25	37.4	44.18	2	1	34	856	23	0.0	19.7
Segment 3	0	380	25	37.4	10.36	2	1	0	0	0	0.0	11.6
Segment 4	0	480	25	37.4	13.09	3	1	0	0	0	0.0	10.5
Segment 5	0	515	25	37.4	14.05	3	1	0	0	0	0.0	11.0
Segment 6	6	375	25	37.4	10.23	4	1	15	367	10	0.0	7.5
Segment 7	0	345	25	37.4	9.41	4	1	0	0	0	0.0	7.0
Segment 8	1	200	25	37.4	5.45	3	1	2	61	2	0.0	5.8
Segment 9	14	635	25	37.4	17.32	4	1	34	856	23	6.0	9.1
Segment 10	1	375	25.0	37.4	10.23	4	1	2	61	2	0.0	7.5
Segment 11	1	250	25.0	37.4	6.82	5	1	2	61	2	0.0	4.6
Segment 12	3	325	25.0	37.4	8.86	6	1	7	183	5	0.0	4.9
Segment 13	3	715	25.0	37.4	19.50	6	1	7	183	5	0.0	8.8
Segment 14	4	905	25.0	37.4	24.68	5	1	10	244	7	0.0	11.3
Segment 15	0	275	25.0	37.4	7.50	6	1	0	0	0	0.0	4.3

Facility	PBFS 16%	LOS F	Longest segment combo? (Y=1)	Longest combo run time (255.1)	Longest combo delay (0.0)
Segment 1	82%	B	1	27.4	0.0
Segment 2	79%	B			
Segment 3	46%	D	1	10.4	0.0
Segment 4	42%	D			
Segment 5	44%	D	1	14.0	0.0
Segment 6	30%	F			
Segment 7	28%	F			
Segment 8	23%	F			
Segment 9	37%	E			
Segment 10	30%	F			
Segment 11	19%	F			
Segment 12	20%	F			
Segment 13	35%	E			
Segment 14	45%	D			
Segment 15	17%	F			

Modeling outcome:
Total clear time is 64.1 minutes

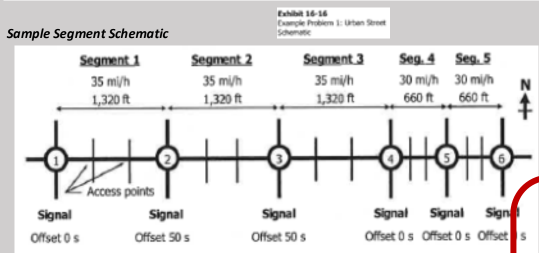
Heritage Ranch – Eastern Entrance

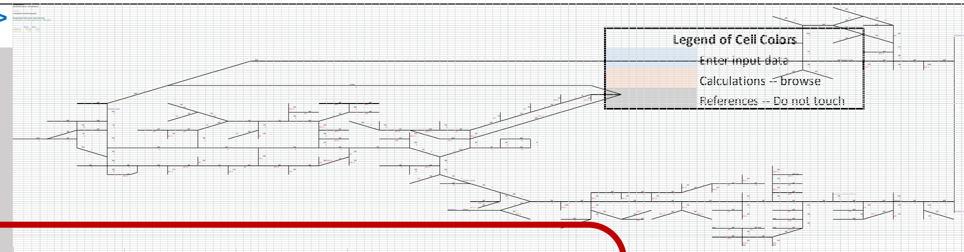


<<<< Schematic Key

Application Schematic >>>

Sample Segment Schematic





Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
765	33	799	2476	116.5

Input

Summary

Number of Segments: 107

Average Network/Facility Operating Speed (MPH): 5.8

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	1	75	25	37.4	2.05	14	1	2	61	2	0.0	0.6
Segment 2	2	455	25	37.4	12.41	11	1	5	122	3	0.0	4.0
Segment 3	9	510	25	37.4	13.91	12	1	22	550	15	1.1	4.0
Segment 4	18	1830	25	37.4	49.91	9	1	44	1100	30	0.0	12.0
Segment 5	17	1920	25	37.4	52.36	10	1	42	1039	28	0.0	11.7
Segment 6	12	370	25	37.4	10.09	11	1	29	733	20	9.9	2.9
Segment 7	8	260	25	37.4	7.09	12	1	20	489	13	6.2	2.1
Segment 8	5	280	25	37.4	7.64	12	1	12	306	8	0.7	2.4
Segment 9	25	1335	25	37.4	36.41	11	1	61	1528	42	5.3	8.5
Segment 10	8	260	25.0	37.4	7.09	11	1	20	489	13	6.2	2.2
Segment 11	14	600	25.0	37.4	16.36	12	1	34	856	23	7.0	4.3
Segment 12	4	285	25.0	37.4	7.77	13	1	10	244	7	0.0	2.3
Segment 13	14	370	25.0	37.4	10.09	13	1	34	856	23	13.2	2.5
Segment 14	4	275	25.0	37.4	7.50	12	1	10	244	7	0.0	2.4
Segment 15	10	250	25.0	37.4	6.82	12	1	24	611	17	9.8	1.9

	PBFS	LOS		765.4	33.3
Facility	23%	F	Longest segment combo? (Y=1)	Longest combo run time	Longest combo delay
Segment 1	2%	F			
Segment 2	16%	F	1	12.4	3.3
Segment 3	16%	F			
Segment 4	48%	D	1	49.9	30.0
Segment 5	47%	D			
Segment 6	12%	F			
Segment 7	8%	F			
Segment 8	10%	F			
Segment 9	34%	E			
Segment 10	9%	F			
Segment 11	17%	F			
Segment 12	9%	F			
Segment 13	10%	F			
Segment 14	9%	F			
Segment 15	8%	F			

Modeling outcome:
Total clear time is 116.5 minutes

River Oaks

River Oaks: Roadway schematic

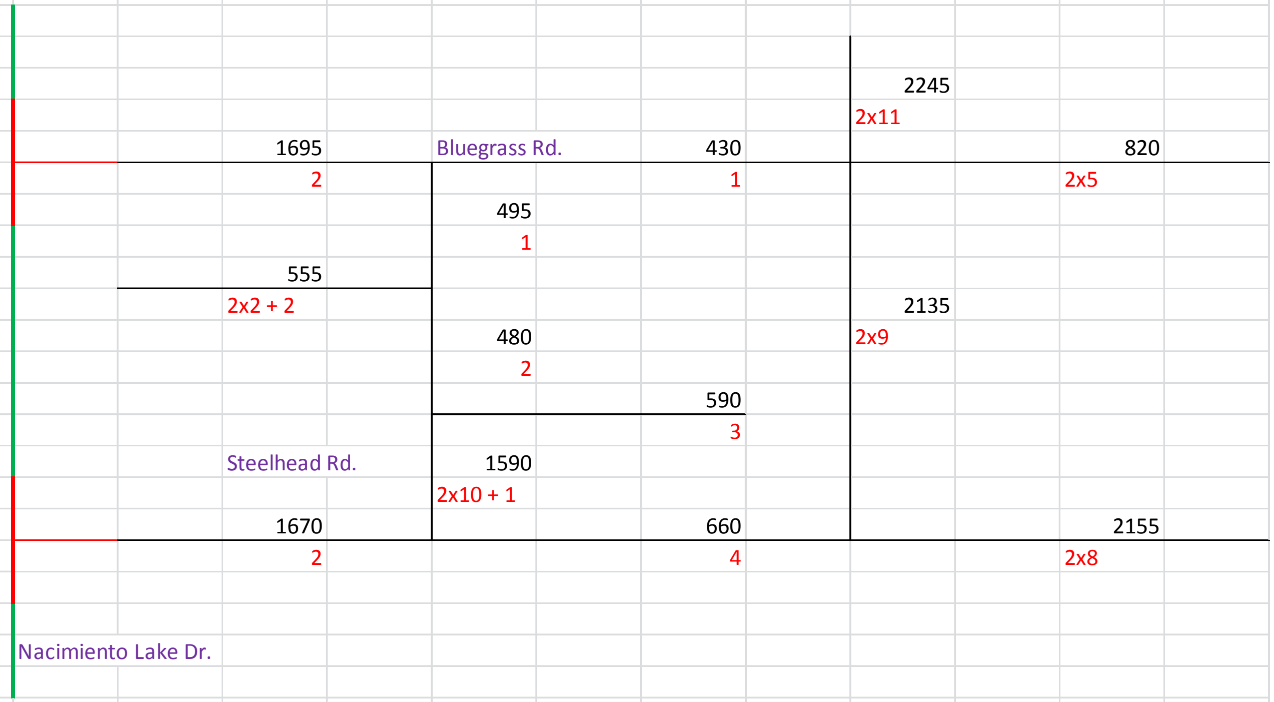
River Oaks

Nacimiento Lake Dr. at Bluegrill Dr. and Steelhead Rd.

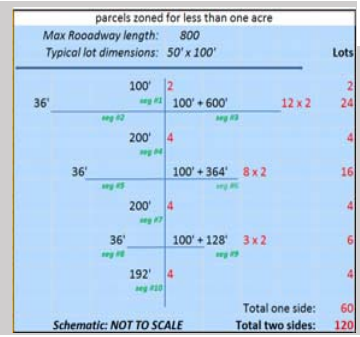
Average Daily Traffic Counts: Source KSS Feuls:

OnNacimiento Lake Dr.: 1296 (1996)

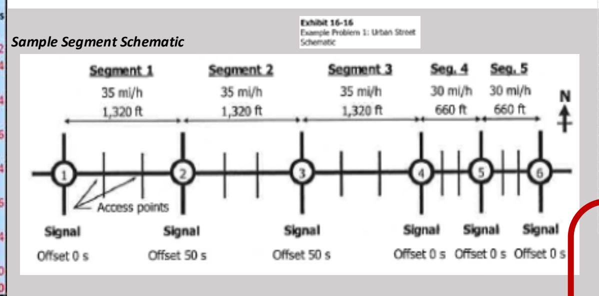
	Sq. Ft.	Acres
Largest Lot:	77,101	1.77
Smallest Lot:	43,560	1.00

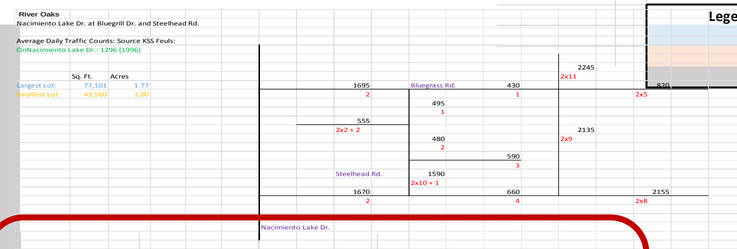


River Oaks: Modeling Summary



<<<< Schematic Key **Application Schematic >>>**





Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
122	37	159	264	13.7

Input

Number of Segments: 14

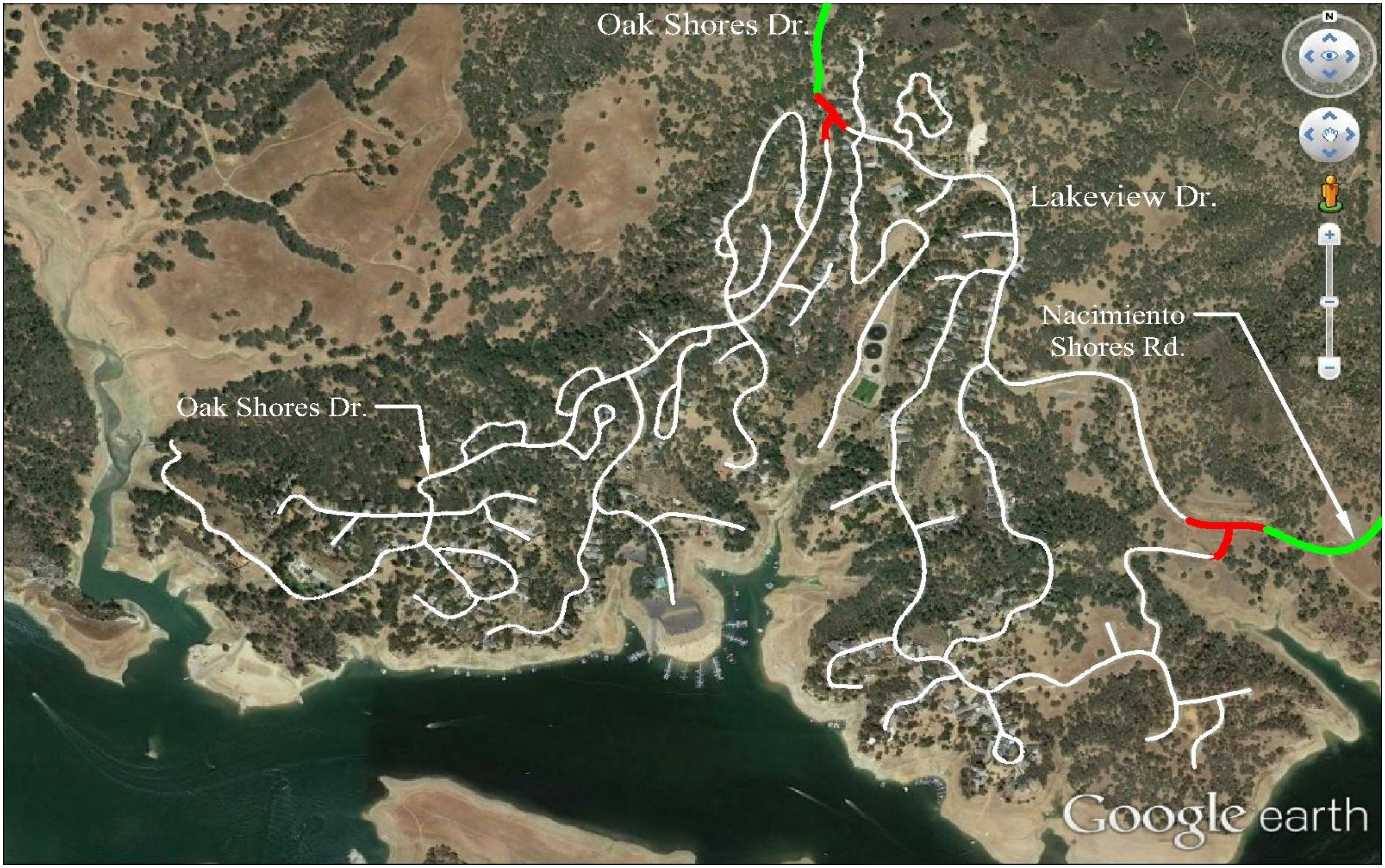
Summary

Average Network/Facility Operating Speed (MPH): 17.4

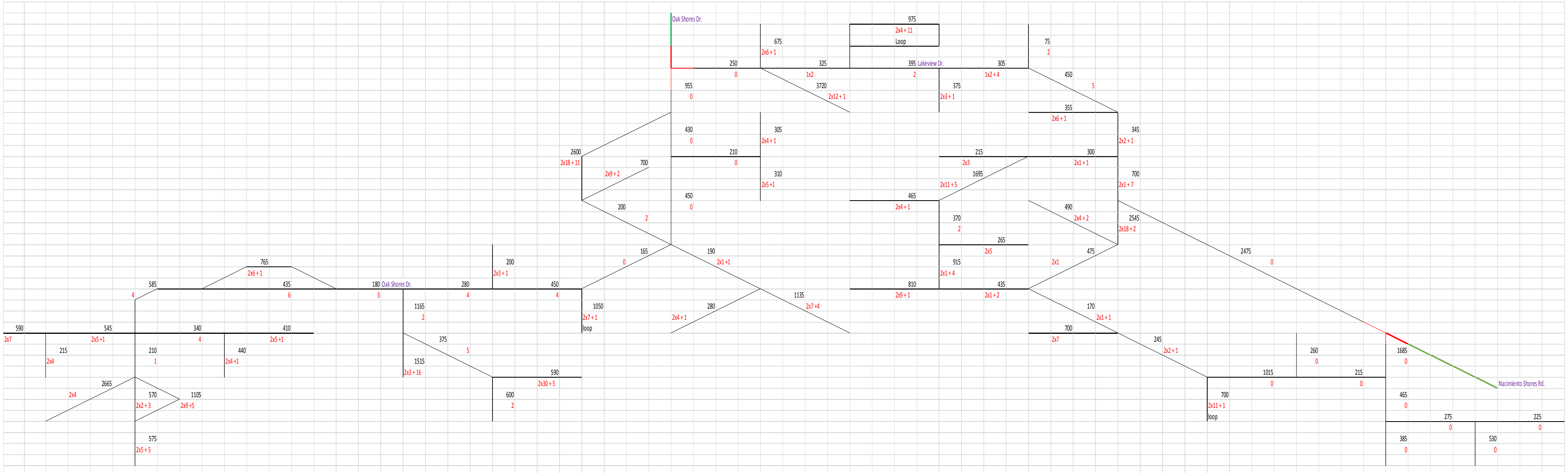
Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed	Facility	PBFS 69%	LOS B	Longest segment combo? (Y=1)	Longest combo run time (122.3)	Longest combo delay (36.7)
Segment 1	2	1695	25	37.4	46.23	1	1	5	122	3	0.0	22.1	Segment 1	89%	A			
Segment 2	1	430	25	37.4	11.73	2	1	2	61	2	0.0	12.4	Segment 2	49%	D			
Segment 3	22	2245	25	37.4	61.23	3	1	54	1344	37	0.0	19.3	Segment 3	77%	B			
Segment 4	10	820	25	37.4	22.36	3	1	24	611	17	0.0	13.9	Segment 4	55%	C			
Segment 5	1	495	25	37.4	13.50	2	1	2	61	2	0.0	13.2	Segment 5	53%	C			
Segment 6	6	555	25	37.4	15.14	3	1	15	367	10	0.0	11.4	Segment 6	46%	D			
Segment 7	2	480	25	37.4	13.09	3	1	5	122	3	0.0	10.5	Segment 7	42%	D			
Segment 8	3	590	25	37.4	16.09	3	1	7	183	5	0.0	11.8	Segment 8	47%	D			
Segment 9	21	1590	25	37.4	43.36	2	1	51	1283	35	0.0	19.6	Segment 9	78%	B			
Segment 10	2	1670	25.0	37.4	45.55	1	1	5	122	3	0.0	22.1	Segment 10	88%	A	1	45.5	3.3
Segment 11	4	660	25.0	37.4	18.00	2	1	10	244	7	0.0	15.0	Segment 11	60%	C	1	18.0	6.7
Segment 12	16	2155	25.0	37.4	58.77	3	1	39	978	27	0.0	19.1	Segment 12	77%	B	1	58.8	26.7
Segment 13	18	2135	25.0	37.4	58.23	3	1	44	1100	30	0.0	19.1	Segment 13	76%	B			

Modeling outcome:
Total clear time is 13.7 minutes

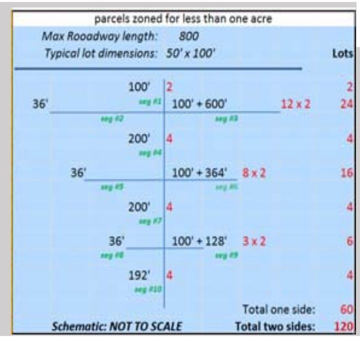
Oak Shores


Oak Shores Dr.
Lakeview Dr.
Nacimiento
Shores Rd.
Oak Shores Dr.
Google earth

Oak Shores: Roadway schematic

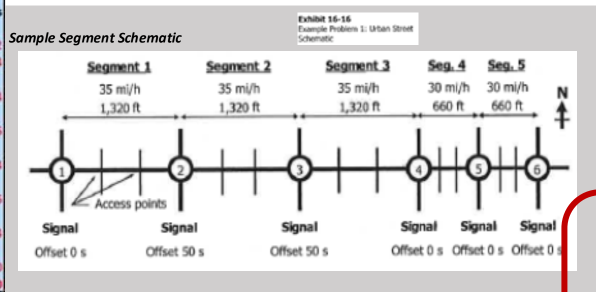


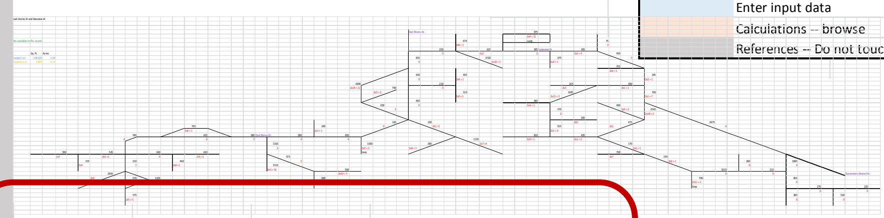
Oak Shores: Modeling Summary



<<<< Schematic Key

Application Schematic >>>





Legend of Cell Colors
Enter input data
Calculations -- browse
References -- Do not touch

Far veh time	Far veh delay	Tot Far time (sec)	Vehs	Total Clear (min)
44	50	94	1569	67.0

Input

Summary

Number of Segments: 76

Average Network/Facility Operating Speed (MPH): 8.7

Segment	Houses on Segment	Segment Length (L_i)	Segment Speed Limit ($S_{fo,i}$)	Speed Constant (Exhibit 17-11)	Segment Running Time (t_R) -- (sec)	Full Stop Rate (intersections traversed)	Segment Directional Lanes	Segment Volume (pax cars)	Queue Length (feet)	Delayed Running Time (sec)	Cumul. Delay (sec)	Segment Operation Speed
Segment 1	0	950	25	37.4	25.91	1	1	0	0	0	0.0	20.3
Segment 2	0	430	25	37.4	11.73	2	1	0	0	0	0.0	12.4
Segment 3	47	2600	25	37.4	70.91	2	1	115	2872	78	7.4	19.6
Segment 4	20	700	25	37.4	19.09	3	1	49	1222	33	14.2	9.3
Segment 5	2	200	25	37.4	5.45	3	1	5	122	3	0.0	5.8
Segment 6	0	210	25	37.4	5.73	3	1	0	0	0	0.0	6.0
Segment 7	9	305	25	37.4	8.32	4	1	22	550	15	6.7	5.3
Segment 8	11	310	25	37.4	8.45	4	1	27	672	18	9.9	5.0
Segment 9	0	450	25	37.4	12.27	3	1	0	0	0	0.0	10.1
Segment 10	3	190	25.0	37.4	5.18	4	1	7	183	5	0.0	4.4
Segment 11	9	280	25.0	37.4	7.64	5	1	22	550	15	7.4	4.2
Segment 12	18	1135	25.0	37.4	30.95	5	1	44	1100	30	0.0	12.7
Segment 13	0	165	25.0	37.4	4.50	4	1	0	0	0	0.0	3.9
Segment 14	15	1050	25.0	37.4	28.64	5	1	37	917	25	0.0	12.2
Segment 15	4	450	25.0	37.4	12.27	5	1	10	244	7	0.0	7.3

Facility	PBFS 35%	LOS E	Longest segment combo? (Y=1)	Longest combo run time 43.8	Longest combo delay 50.0
Segment 1	81%	B			
Segment 2	49%	D			
Segment 3	78%	B			
Segment 4	37%	E			
Segment 5	23%	F			
Segment 6	24%	F			
Segment 7	21%	F			
Segment 8	20%	F			
Segment 9	41%	D			
Segment 10	18%	F	1	5.2	5.0
Segment 11	17%	F	1	7.6	15.0
Segment 12	51%	C	1	31.0	30.0
Segment 13	16%	F			
Segment 14	49%	D			
Segment 15	29%	F			

Modeling outcome:
Total clear time is 67.0 minutes

This page intentionally left blank

5.0 Background Information

Background 1: Census Data on Household Size & Auto Availability

AVERAGE HOUSEHOLD SIZE OF OCCUPIED HOUSING UNITS BY TENURE

Universe: Occupied housing units

2009-2013 American Community Survey 5-Year Estimates

	California	
	Estimate	Margin of Error
Total:	2.94	+/-0.01
Owner occupied	2.98	+/-0.01
Renter occupied	2.88	+/-0.01

Average household size

2.98

TENURE BY VEHICLES AVAILABLE

Universe: Occupied housing units

2009-2013 American Community Survey 5-Year Estimates

	California	
	Estimate	Margin of Error
Total:	12,542,460	+/-20,542
Owner occupied:	6,939,104	+/-35,627
No vehicle available	190,309	+/-3,088
1 vehicle available	1,609,048	+/-9,435
2 vehicles available	2,936,622	+/-18,207
3 vehicles available	1,440,200	+/-11,562
4 vehicles available	534,717	+/-6,149
5 or more vehicles available	228,208	+/-3,149
Renter occupied:	5,603,356	+/-19,367
No vehicle available	783,643	+/-5,203
1 vehicle available	2,436,631	+/-11,478
2 vehicles available	1,757,120	+/-10,360
3 vehicles available	454,628	+/-6,314
4 vehicles available	125,119	+/-2,947
5 or more vehicles available	46,215	+/-1,663

Owners

Average autos per HH	2.206482
6,939,104	
0	
1,609,048	
5,873,244	
4,320,600	
2,138,868	
1,369,248	
15,311,008	

HOUSEHOLD SIZE BY VEHICLES AVAILABLE

Universe: Households

2009-2013 American Community Survey 5-Year Estimates

	California	
	Estimate	Margin of Error
Total:	12,542,460	+/-20,542
No vehicle available	973,952	+/-5,927
1 vehicle available	4,045,679	+/-10,805
2 vehicles available	4,693,742	+/-15,712
3 vehicles available	1,894,828	+/-10,177
4 or more vehicles available	934,259	+/-7,267
1-person household:	3,040,221	+/-9,441
No vehicle available	536,599	+/-4,131
1 vehicle available	2,050,833	+/-8,494
2 vehicles available	364,812	+/-4,172
3 vehicles available	62,165	+/-1,731
4 or more vehicles available	25,812	+/-1,066
2-person household:	3,749,732	+/-10,400
No vehicle available	211,328	+/-3,146
1 vehicle available	971,950	+/-6,474
2 vehicles available	1,980,069	+/-8,509
3 vehicles available	457,793	+/-4,380
4 or more vehicles available	128,592	+/-2,619
3-person household:	2,048,520	+/-11,352
No vehicle available	92,441	+/-2,096
1 vehicle available	445,940	+/-5,082
2 vehicles available	842,637	+/-7,558
3 vehicles available	515,344	+/-5,598
4 or more vehicles available	152,158	+/-2,472
4-or-more-person household:	3,703,987	+/-11,416
No vehicle available	133,584	+/-2,658
1 vehicle available	576,956	+/-5,395
2 vehicles available	1,506,224	+/-8,962
3 vehicles available	859,526	+/-6,704
4 or more vehicles available	627,697	+/-5,527

3-psn Households

Average autos per HH 2.16646

2,048,520

0

445,940

1,685,274

1,546,032

760,790

4,438,036

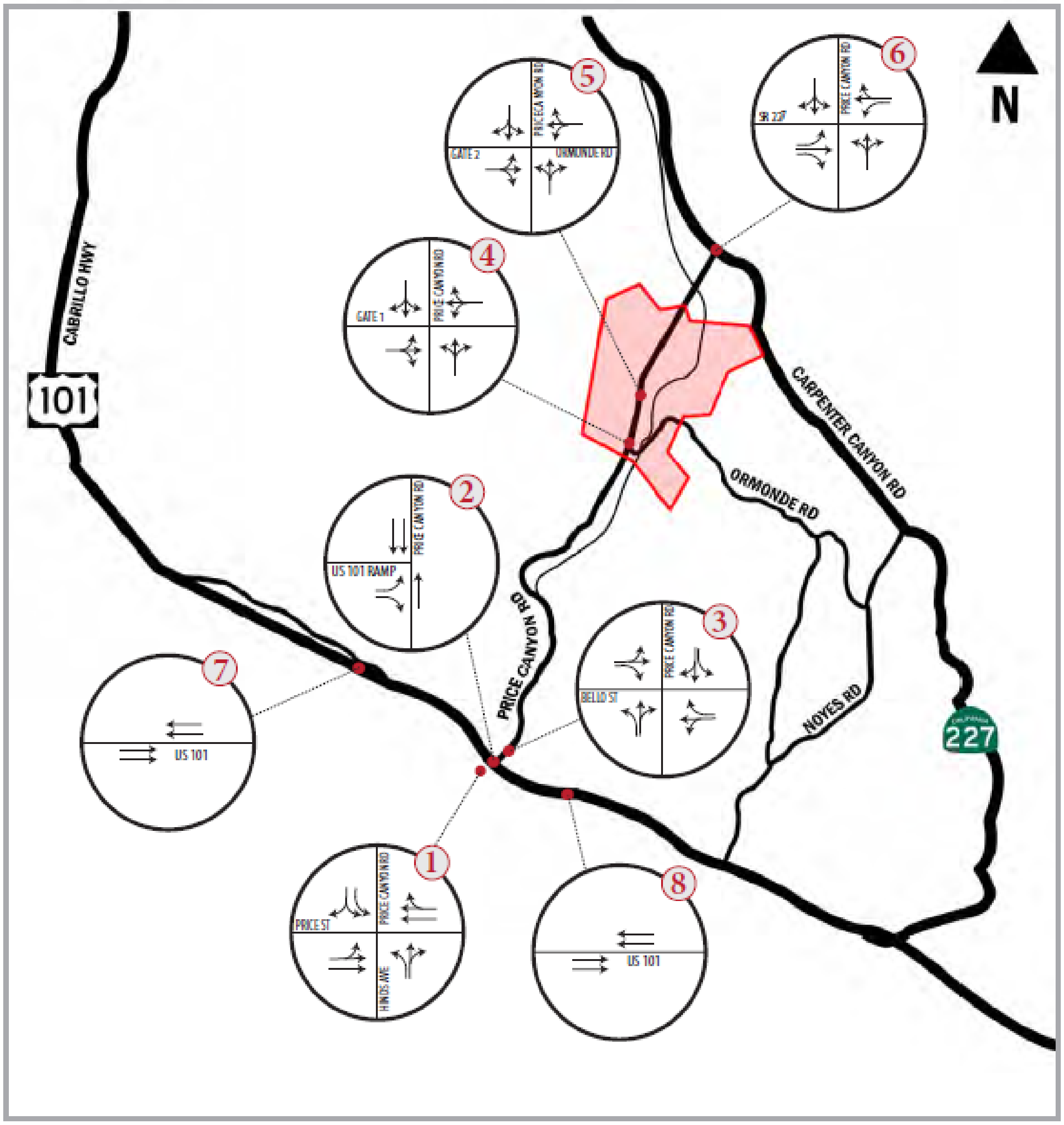
2.16646

Background 2: Excerpts from Price Canyon Traffic Impact Study

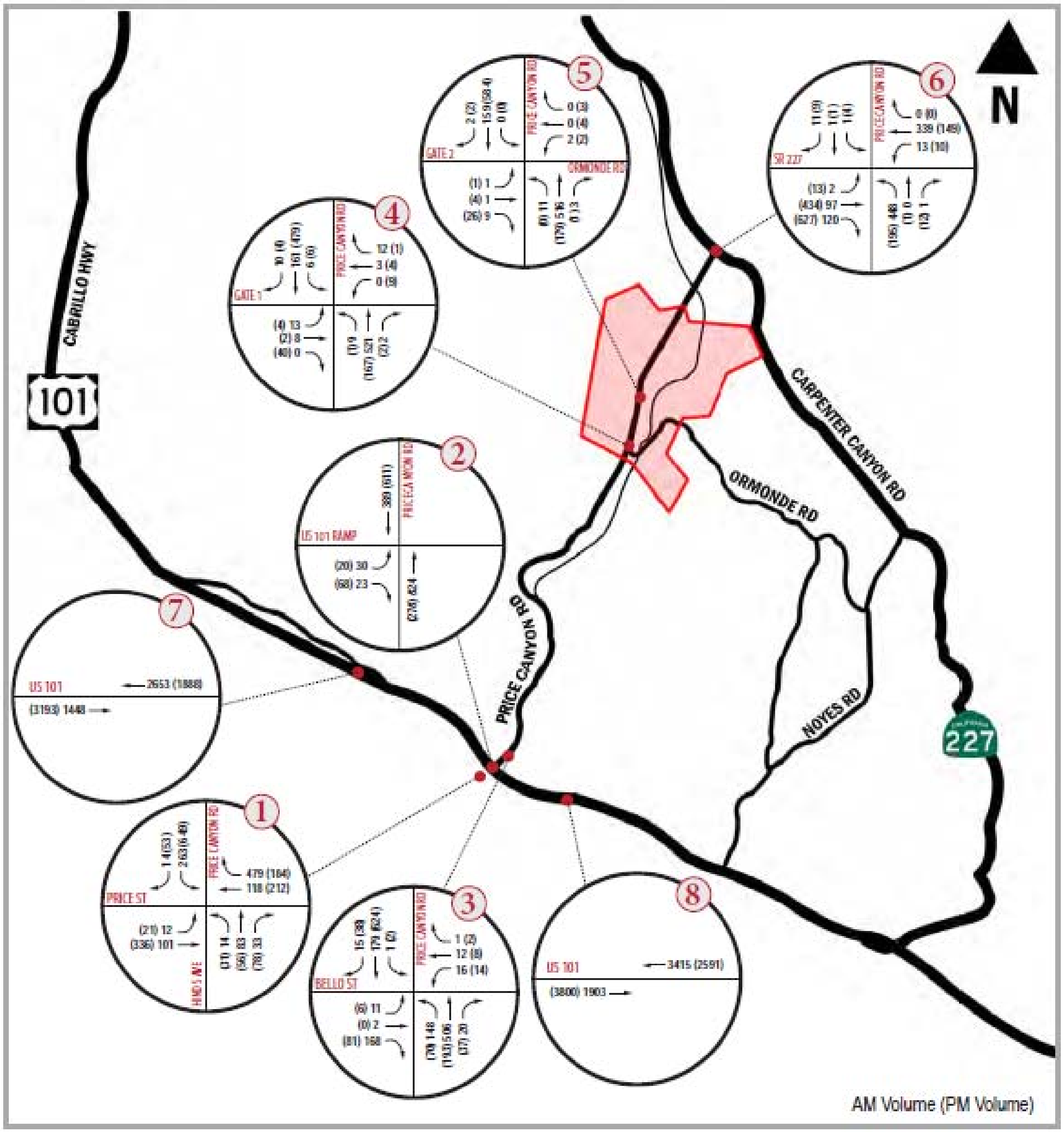
FM O&G - Arroyo Grande Oil Field - Phase V Development Project
San Luis Obispo County, California

Table 5: Existing Level of Service Conditions		**Level of Service (Delay in Seconds)**	
		AM	**PM**
1. Price Street and Price Canyon Road (Hinds Avenue) *Signalized*	Intersection	B (19)	C (26)
2. SB US 101 Ramp and Price Canyon Road *One-Way Southbound Stop Control*	**Eastbound**	**D (29)**	C (17)
3. Bello Street and Price Canyon Road *Two-Way North-South Stop Control*	Northbound Left	A (8)	A (9)
	Southbound Left	A (9)	A (8)
	Westbound	**F (61)**	**D (27)**
	Eastbound	B (14)	C (15)
4. Ormonde Rd/Gate #1 and Price Canyon Road *Two-Way North-South Stop Control*	Northbound	A (8)	A (9)
	Southbound	A (9)	A (8)
	Westbound	B (14)	C (17)
	Eastbound	C (20)	B (13)
5. Gate #2 and Price Canyon Road *Two-Way North-South Stop Control*	Northbound	A (8)	A (9)
	Southbound	A (9)	A (8)
	Westbound	C (16)	C (16)
	Eastbound	B (10)	B (14)
6. SR 227 and Price Canyon Road *Signalized*	Intersection	B (14)	A (9)

Source: TRAFFIC IMPACT STUDY FOR THE PHASE V DEVELOPMENT FOR THE ARROYO GRANDE OIL FIELD, Prepared by: C2 Consult, Inc., December 2013. http://www.slocounty.ca.gov/Assets/PL/environmental/plains/Planning/Traffic+Study+C2+-+12-13.pdf



Source: TRAFFIC IMPACT STUDY FOR THE PHASE V DEVELOPMENT FOR THE ARROYO GRANDE OIL FIELD, Prepared by: C2 Consult, Inc., December 2013. [*http://www.slocounty.ca.gov/Assets/PL/environmental/plains/Planning/Traffic+Study+C2+-+12-13.pdf*](http://www.slocounty.ca.gov/Assets/PL/environmental/plains/Planning/Traffic+Study+C2+-+12-13.pdf)



Source: TRAFFIC IMPACT STUDY FOR THE PHASE V DEVELOPMENT FOR THE ARROYO GRANDE OIL FIELD, Prepared by: C2 Consult, Inc., December 2013. http://www.slocounty.ca.gov/Assets/PL/environmental/plains/Planning/Traffic+Study+C2+-+12-13.pdf

This page intentionally left blank

Appendix 3: Additional Details on Fire Behavior Modeling

Single-Access Subdivisions Assessment Project:

Developing a Planning Tool for Evaluating Proposed Developments Accessible by Dead-End Roads

Prepared for

CAL FIRE and the California Board of Forestry and Fire Protection

By

California Polytechnic State University, San Luis Obispo

CAL POLY
SAN LUIS OBISPO

June 2016

This page intentionally left blank

Table of Contents

This page intentionally left blank

1.0 INTRODUCTION

This appendix includes multiple items associated with the fire behavior predictions in this document. In the main report, all fire behavior predictions employed the same overlying principals that were utilized by Cal Fire's Fire & Resource Assessment Program when they developed the state's Fire Hazard Severity Zones. To that end, our intent was to provide reasonable fire behavior in mature vegetation (i.e., no mitigation activities) during normally severe fire weather (a term commonly used by fire behavior experts). Note, the environmental site conditions in which fire behavior was simulated was not intended to convey "worst case" conditions, but rather express potential fire behavior near the 80th percentile. In this appendix, we also include fire behavior predictions of treated vegetation (using identical weather inputs) to illustrate the potential impacts of mitigation.

We remind the reader that these fire behavior predictions are purposefully broad in nature and do not reflect the myriad of combinations of fuels, weather and topography that are found in California. For the most accurate predictions for a given site, a fire behavior expert would be needed to needed to model the specific site conditions found at a given locale. In future iterations of this process, we suggest creating a web-based platform in which a user could obtain the exact same fire behavior conditions as was employed when formulating the state's Fire Hazard Severity Zones.

The specific sections of this appendix include the following items:

Section 2.0 - Inputs utilized in NEXUS software for fire behavior predictions

- Mature vegetation condition
- Mitigated vegetation condition

Section 3.0 – Photo guide of both mature and mitigated vegetation types

- Grass
- Shrubs
- Conifer forest
- Broadleaf forest

Section 4.0 - Fire behavior predictions for mature and mitigated vegetation types

- Rate of spread
- Flame Length

Section 5.0 - Fire behavior lookup tables for all vegetation types under both mature and mitigated conditions

This page intentionally left blank

2.0 INPUTS UTILIZED IN NEXUS SOFTWARE FOR FIRE BEHAVIOR PREDICTIONS

Table 1 below presents Inputs utilized for fire behavior predictions in mature vegetation types within NEXUS software.

Appendix 3-Table 1: Inputs Utilized for Fire Behavior Predictions – Mature Vegetation Condition

Vegetation Type	Grass	Shrub	Coniferous Forest	Broadleaf Forest
Simulation Type	Surface	Shrub	Conifer	Conifer
Fuel Model	GR4: Moderately Coarse Continutous Grass	SH5: Heavy, grass/shrub load	TL4: Moderate load, includes small diamater downed logs	TL6: Moderate load, less compact broadleaf litter
Low Fuel Model				
Wind Reduction Factor	0.1	0.1	0.1	0.1
Spread Rate Multiplier	1	1	1	1
Fuel Load Multiplier	1	1	1	1
Intensity Multiplier	1	1	1	1
High Fuel Model				
Wind Reduction Factor		0.1		
Spread Rate Multiplier		1	1	1
Fuel Load Multiplier		1		
Intensity Multiplier		1		
Dead Moisture (%)				
1-hr	3	3	3	3
10-hr		4	4	4
100-hr			5	5
Live Moisture (%)				
Live Herbaceous	30	30		
Live Woody		60	60	60
Canopy Fuels				
Canopy Bulk Density (kg/m3)		0.3	0.3	0.1
Canopy Base Height (feet)			5	5
Available Canopy Fuel Load (tons/acre)			10	10
Foliar Moisture Content (%)			100	100
Miscellaneous				
Shrub Transition Flame Length (feet)		0		
Wind & Slope				
Open Wind Speed (mph)	0-60	0-60	0-60	0-60
Slope (%)	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85
Wind Direction (degrees)	0	0	0	0

Table 2 below presents Inputs utilized for fire behavior predictions in mitigated vegetation types within NEXUS software.

Appendix 3-Table 2: Inputs Utilized for Fire Behavior Predictions –Mitigated Vegetation Condition

Vegetation Type	Grass	Shrub	Coniferous Forest	Broadleaf Forest
Simulation Type	Surface	Shrub	Conifer	Conifer
Fuel Model	GR1: Short, sparse dry climate grass	SH1: Low load dry climate shrub	TL1: Low load compact conifer litter	TL2: Low load broadleaf litter
Low Fuel Model				
Wind Reduction Factor	0.1	0.1	0.1	0.1
Spread Rate Multiplier	1	1	1	1
Fuel Load Multiplier	1	1	1	1
Intensity Multiplier	1	1	1	1
High Fuel Model				
Wind Reduction Factor		0.1		
Spread Rate Multiplier		1	1	1
Fuel Load Multiplier		1		
Intensity Multiplier		1		
Dead Moisture (%)				
1-hr	3	3	3	3
10-hr		4	4	4
100-hr			5	5
Live Moisture (%)				
Live Herbaceous	30	30		
Live Woody		60	60	60
Canopy Fuels				
Canopy Bulk Density (kg/m3)		0.1	0.04	0.04
Canopy Base Height (feet)			50	20
Available Canopy Fuel Load (tons/acre)			2	2
Foliar Moisture Content (%)			100	100
Miscellaneous				
Shrub Transition Flame Length (feet)		0		
Wind & Slope				
Open Wind Speed (mph)	0-60	0-60	0-60	0-60
Slope (%)	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85	0, 13, 33, 48, 65, 85
Wind Direction (degrees)	0	0	0	0

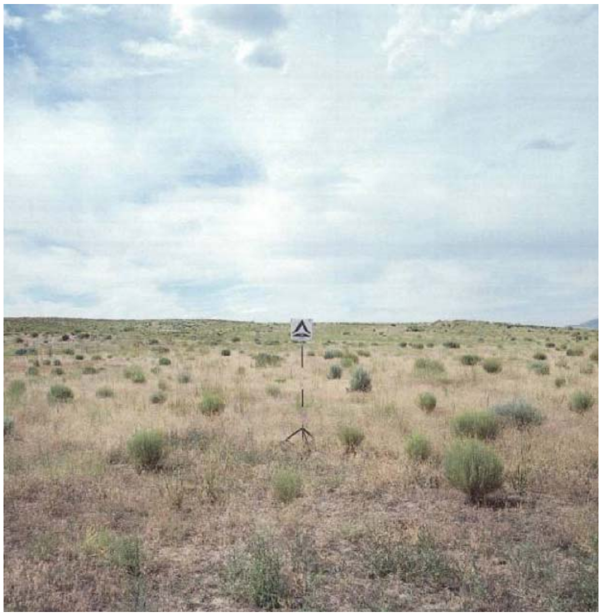
3.0 PHOTO GUIDE OF BOTH MATURE AND MITIGATED VEGETATION TYPES

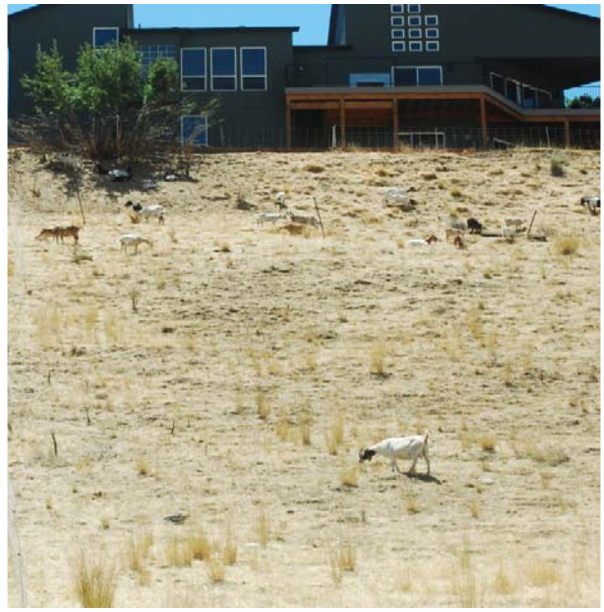
Examples of Mature Grass Vegetation Class

Examples of mature grass vegetation class: Potential examples include grasslands, oak savannahs, meadows, and others.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory.

Examples of Mitigated Grass Vegetation Class





Examples of mitigated grass vegetation class: Mitigated grasslands could result from a number of fuel treatments including mowing or grazing.

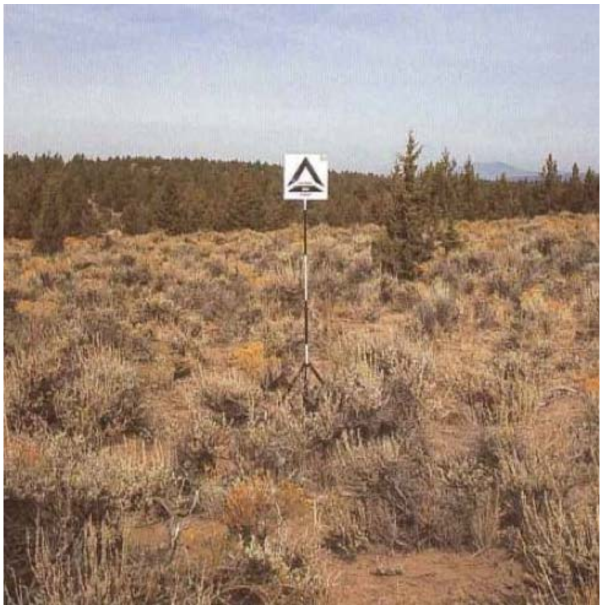
Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory and by the Fire Adapted Network.

Examples of Mature Shrub Vegetation Class

Mature shrub vegetation class: Potential examples include chaparral, coastal sage scrub, Great Basin sagebrush, and others.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory.

Examples of Mitigated Shrub Vegetation Class



Mitigated shrub vegetation class Mitigated shrublands could result from a number of fuel treatments including mastication or prescribed fire.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory.

Examples of Mature Coniferous Forest Vegetation Class

Mature coniferous forest vegetation type: Potential examples include mixed-conifers, ponderosa pine, redwood, Douglas-fir, and others.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory.

Examples of Mitigated Coniferous Forest Vegetation Class

Mitigated coniferous forest vegetation type: Mitigated coniferous forest could result from a number of fuel treatments including thinning, pile and burn or prescribed fire.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory and C.A. Dicus.

Examples of Mature Broadleaf Vegetation Class

Mature broadleaf forest vegetation type: Potential examples include closed canopy oak woodlands, tanoak, madrone, bay laurel, and others.

Photos obtained from the Natural Fuels Photo Series published by the Pacific Northwest Forest Fire Laboratory.

Example of Mitigated Broadleaf Forest Vegetation Class

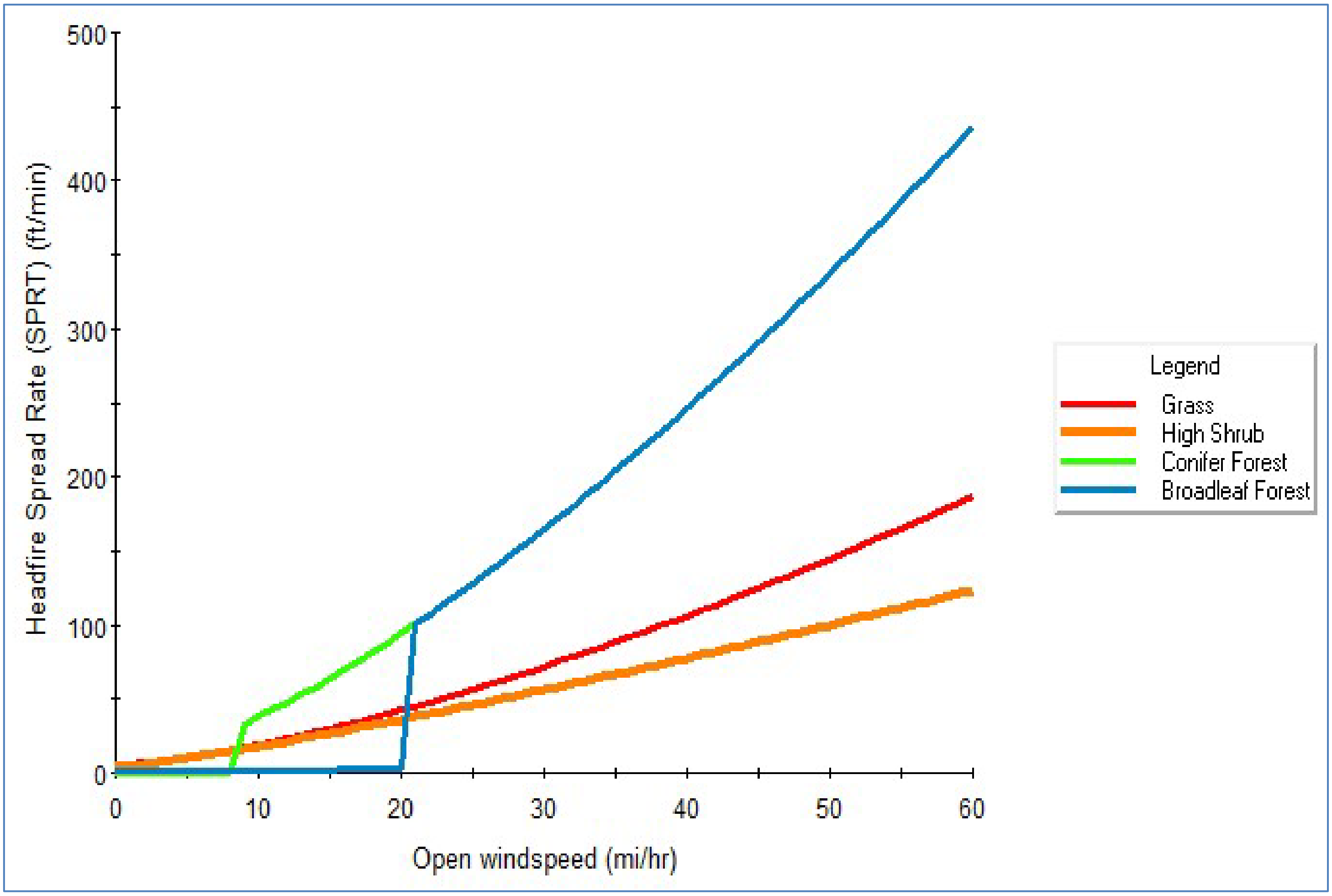
Mitigated Broadleaf Forest vegetation type: Mitigated broadleaf forest could result from a number of fuel treatments including thinning, prescribed fire, or others. Photo shows oak stand treated via mastication adjacent to untreated oak stand.

Photo provided by C.A. Dicus.

4.0 FIRE BEHAVIOR PREDICTIONS

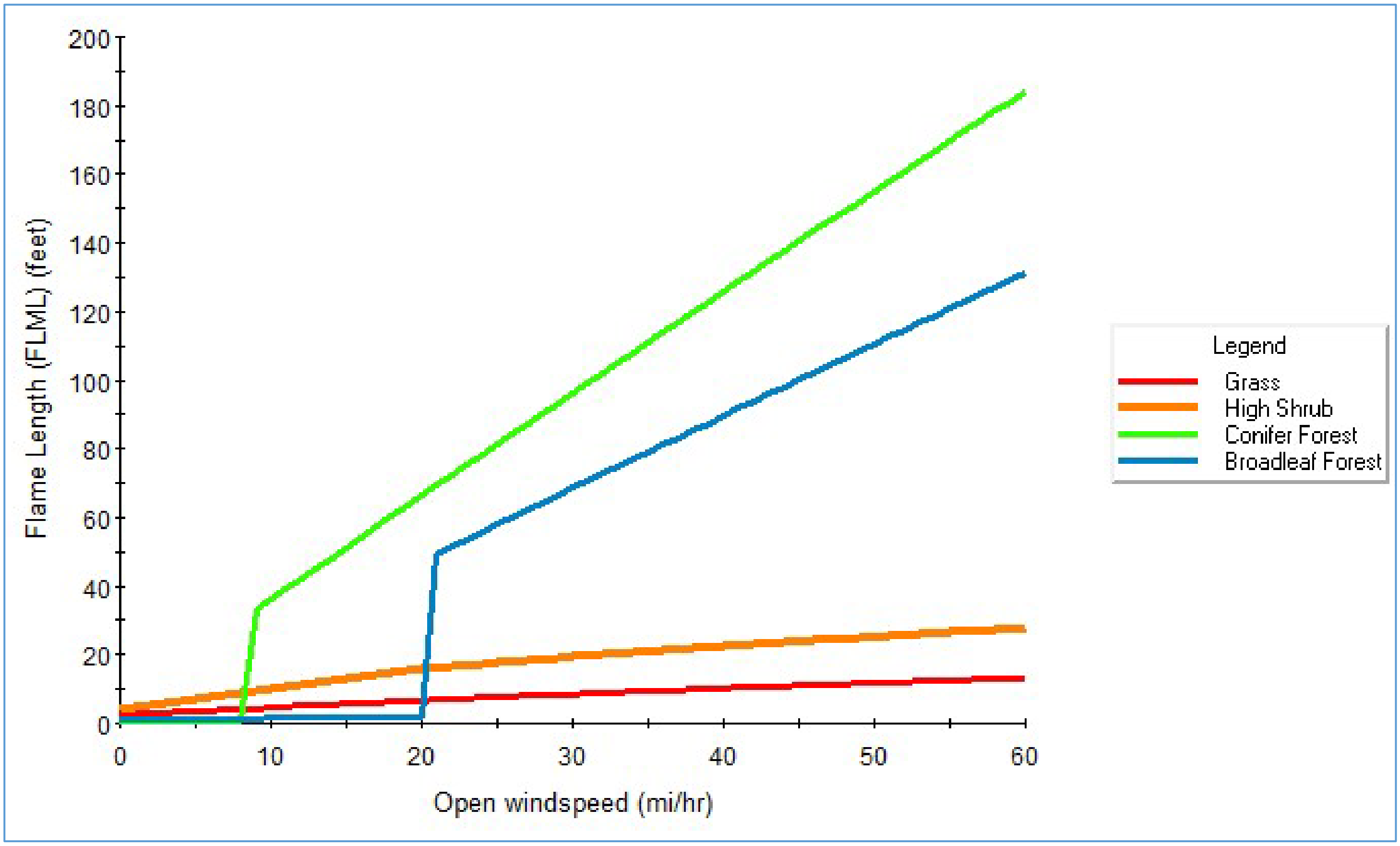
Predicted rate of spread for mature vegetation conditions

Large changes in the forest types reflect the transition from a surface fire to a crown fire.



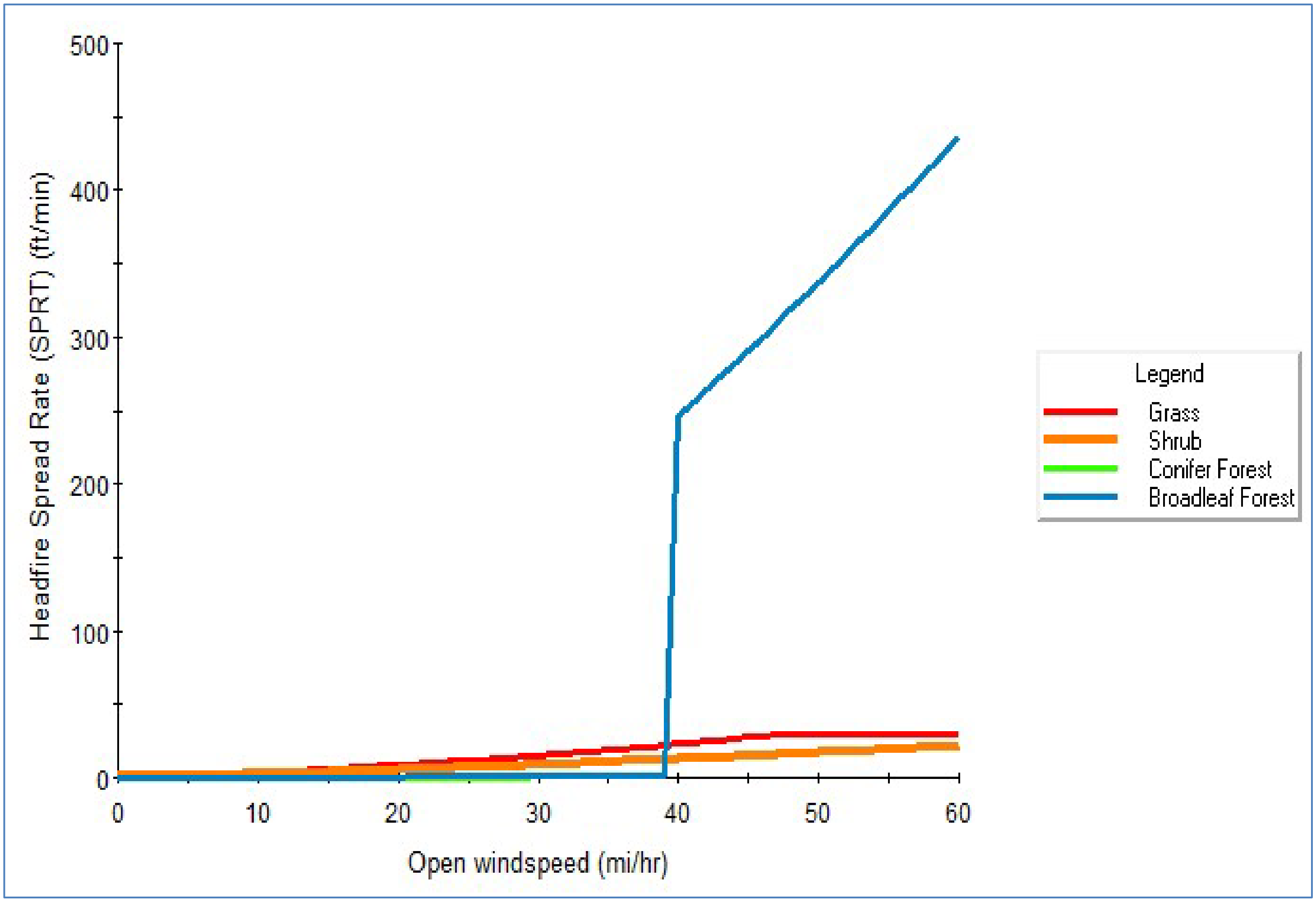
Predicted flame length for mature vegetation conditions

Large changes in the forest types reflect the transition from a surface fire to a crown fire.



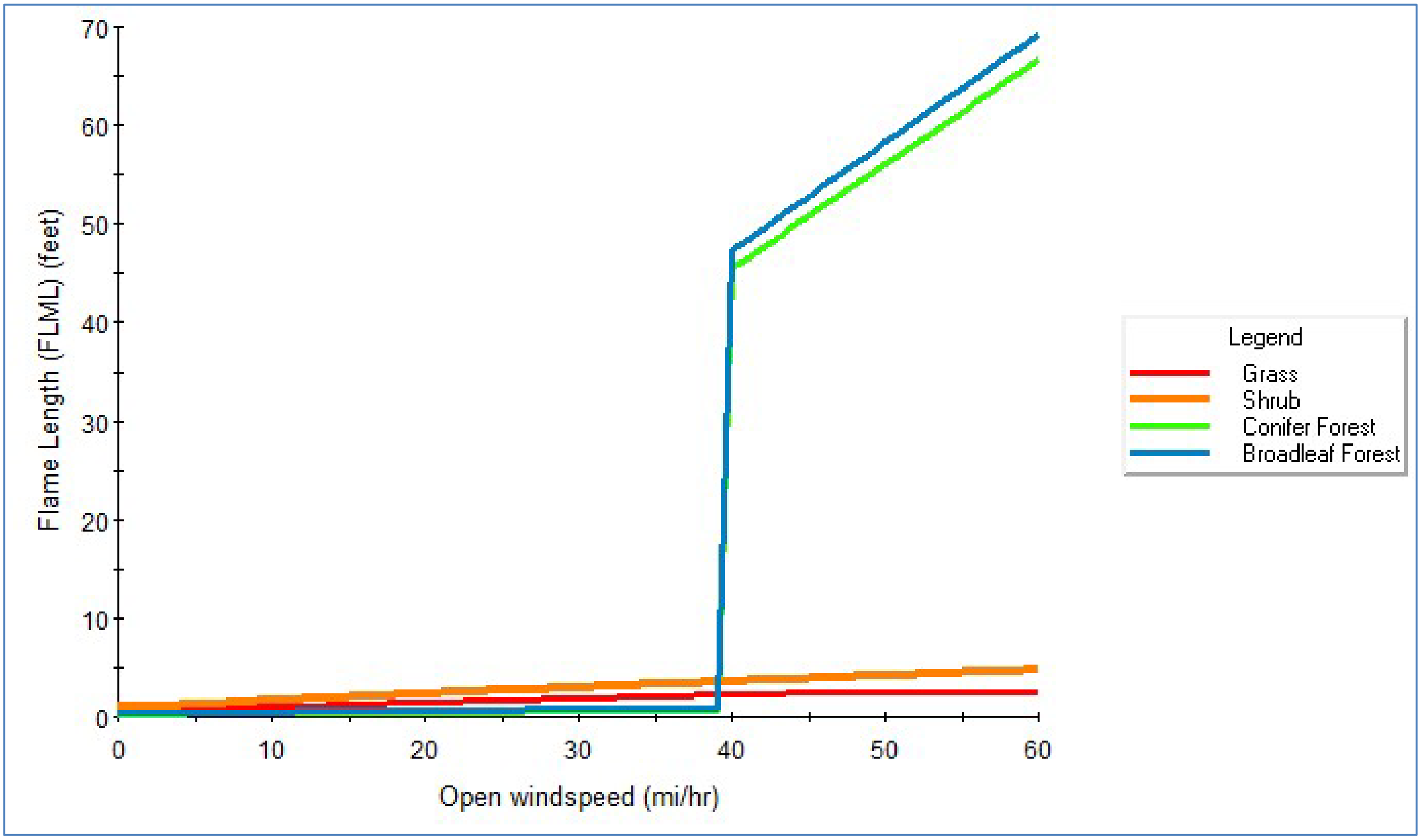
Predicted rate of spread for mitigated vegetation conditions.

Large changes in the forest types reflect the transition from a surface fire to a crown fire.



Predicted flame length for mitigated vegetation conditions.

Large changes in the forest types reflect the transition from a surface fire to a crown fire



5.0 FIRE BEHAVIOR LOOKUP TABLES

Table 3: Fire behavior lookup tables for mature grass vegetation types

Vegetation: Grass (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 6'/min FL: 3'	ROS: 19'/min FL: 5'	ROS: 42'/min FL: 7'	ROS: 71'/min FL: 9'	ROS: 106'/min FL: 10'	ROS: 144'/min FL: 12'
1-25	ROS: 9'/min FL: 3'	ROS: 23'/min FL: 5'	ROS: 46'/min FL: 7'	ROS: 75'/min FL: 9'	ROS: 110'/min FL: 10'	ROS: 148'/min FL: 12'
26-40	ROS: 29'/min FL: 6'	ROS: 42'/min FL: 7'	ROS: 65'/min FL: 8'	ROS: 95'/min FL: 10'	ROS: 129'/min FL: 11'	ROS: 168'/min FL: 13'
41-55	ROS: 55'/min FL: 8'	ROS: 69'/min FL: 8'	ROS: 91'/min FL: 10'	ROS: 121'/min FL: 11'	ROS: 155'/min FL: 12'	ROS: 194'/min FL: 14'
56-75	ROS: 96'/min FL: 10'	ROS: 109'/min FL: 10'	ROS: 132'/min FL: 11'	ROS: 162'/min FL: 12'	ROS: 196'/min FL: 14'	ROS: 234'/min FL: 15'
>75	ROS: 159'/min FL: 12'	ROS: 173'/min FL: 13'	ROS: 196'/min FL: 14'	ROS: 225'/min FL: 14'	ROS: 260'/min FL: 15'	ROS: 298'/min FL: 16'

Table 4: Fire behavior lookup tables for mitigated grass vegetation type

Vegetation: Grass (Mitigated)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 1'/min FL: 0'	ROS: 4'/min FL: 1'	ROS: 9'/min FL: 2'	ROS: 15'/min FL: 3'	ROS: 23'/min FL: 4'	ROS: 30'/min FL: 5'
1-25	ROS: 2'/min FL: 0'	ROS: 5'/min FL: 1'	ROS: 10'/min FL: 2'	ROS: 16'/min FL: 3'	ROS: 23'/min FL: 4'	ROS: 30'/min FL: 5'
26-40	ROS: 7'/min FL: 2'	ROS: 9'/min FL: 2'	ROS: 14'/min FL: 3'	ROS: 21'/min FL: 4'	ROS: 28'/min FL: 5'	ROS: 35'/min FL: 5'
41-55	ROS: 7'/min FL: 3'	ROS: 9'/min FL: 3'	ROS: 14'/min FL: 4'	ROS: 21'/min FL: 4'	ROS: 28'/min FL: 5'	ROS: 35'/min FL: 6'
56-75	ROS: 22'/min FL: 4'	ROS: 25'/min FL: 4'	ROS: 30'/min FL: 5'	ROS: 36'/min FL: 5'	ROS: 44'/min FL: 6'	ROS: 51'/min FL: 7'
>75	ROS: 37'/min FL: 5'	ROS: 40'/min FL: 6'	ROS: 44'/min FL: 7'	ROS: 51'/min FL: 14'	ROS: 59'/min FL: 7'	ROS: 66'/min FL: 8'

Table 5: Fire behavior lookup table for mature shrub vegetation type

Vegetation: Shrubs (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 4'/min FL: 4'	ROS: 18'/min FL: 10'	ROS: 36'/min FL: 16'	ROS: 56'/min FL: 19'	ROS: 78'/min FL: 22'	ROS: 145'/min FL: 25'
1-25	ROS: 6'/min FL: 5'	ROS: 20'/min FL: 11'	ROS: 38'/min FL: 16'	ROS: 58'/min FL: 20'	ROS: 80'/min FL: 23'	ROS: 102'/min FL: 25'
26-40	ROS: 18'/min FL: 10'	ROS: 32'/min FL: 15'	ROS: 50'/min FL: 18	ROS: 70'/min FL: 21'	ROS: 92'/min FL: 24'	ROS: 114'/min FL: 27'
41-55	ROS: 33'/min FL: 15'	ROS: 47'/min FL: 18'	ROS: 66'/min FL: 21'	ROS: 86'/min FL: 23'	ROS: 107'/min FL: 26'	ROS: 130'/min FL: 28'
56-75	ROS: 96'/min FL: 20'	ROS: 72'/min FL: 22'	ROS: 90'/min FL: 24'	ROS: 110'/min FL: 26'	ROS: 132'/min FL: 29'	ROS: 154'/min FL: 31'
>75	ROS: 96'/min FL: 25'	ROS: 110'/min FL: 26'	ROS: 129'/min FL: 28'	ROS: 149'/min FL: 30'	ROS: 170'/min FL: 32'	ROS: 193'/min FL: 34'

Table 6: Fire behavior lookup table for mitigated shrub vegetation type

Vegetation: Shrubs (Mitigated)						
	Open Wind Speed (mph)					
Slope (%)	**0**	**10**	**20**	**30**	**40**	**50**
0	ROS: 1'/min FL: 0'	ROS: 3'/min FL: 1'	ROS: 5'/min FL: 2'	ROS: 9'/min FL: 3'	ROS: 13'/min FL: 4'	ROS: 17'/min FL: 5'
1-25	ROS: 1'/min FL: 0'	ROS: 3'/min FL: 1'	ROS: 6'/min FL: 2'	ROS: 9'/min FL: 3'	ROS: 13'/min FL: 4'	ROS: 18'/min FL: 5'
26-40	ROS: 4'/min FL: 1'	ROS: 5'/min FL: 2'	ROS: 8'/min FL: 3'	ROS: 9'/min FL: 4'	ROS: 16'/min FL: 5'	ROS: 20'/min FL: 6'
41-55	ROS: 4'/min FL: 2'	ROS: 5'/min FL: 3'	ROS: 8'/min FL: 4'	ROS: 12'/min FL: 4'	ROS: 16'/min FL: 5'	ROS: 20'/min FL: 6'
56-75	ROS: 12'/min FL: 4'	ROS: 13'/min FL: 4'	ROS: 16'/min FL: 5'	ROS: 20'/min FL: 6'	ROS: 23'/min FL: 6'	ROS: 28'/min FL: 7'
>75	ROS: 19'/min FL: 6'	ROS: 21'/min FL: 7'	ROS: 24'/min FL: 7'	ROS: 27'/min FL: 8'	ROS: 31'/min FL: 19'	ROS: 35'/min FL: 22'

Table 7: Fire behavior lookup table for mature coniferous forest vegetation type

Vegetation: Coniferous Forest (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: <1'/min FL: <1'	ROS: 38'/min FL: 36'	ROS: 94'/min FL: 66'	ROS: 165'/min FL: 96'	ROS: 246'/min FL: 126'	ROS: 337'/min FL: 155'
1-25	ROS: <1'/min FL: <1'	ROS: 39'/min FL: 37'	ROS: 96'/min FL: 67'	ROS: 166'/min FL: 97'	ROS: 248'/min FL: 126'	ROS: 338'/min FL: 156'
26-40	ROS: 1'/min FL: 1'	ROS: 47'/min FL: 42'	ROS: 103'/min FL: 71'	ROS: 174'/min FL: 100'	ROS: 255'/min FL: 129'	ROS: 346'/min FL: 158'
41-55	ROS: 2'/min FL: 1'	ROS: 57'/min FL: 48'	ROS: 114'/min FL: 75'	ROS: 184'/min FL: 104'	ROS: 266'/min FL: 132'	ROS: 356'/min FL: 161'
56-75	ROS: 40'/min FL: 37'	ROS: 73'/min FL: 56'	ROS: 130'/min FL: 82'	ROS: 200'/min FL: 110'	ROS: 282'/min FL: 138'	ROS: 372'/min FL: 166'
>75	ROS: 65'/min FL: 52'	ROS: 98'/min FL: 68'	ROS: 155'/min FL: 92'	ROS: 225'/min FL: 118'	ROS: 307'/min FL: 146'	ROS: 398'/min FL: 173'

Table 8: Fire behavior lookup table for mitigated coniferous forest vegetation type

Vegetation: Coniferous Forest (Mitigated)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: <1'/min FL: <1'	ROS: <1'/min FL: 1'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 246'/min FL: 16'	ROS: 337'/min FL: 20'
1-25	ROS: <1'/min FL: <1'	ROS: <1'/min FL: 1'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 248'/min FL: 16'	ROS: 339'/min FL: 20'
26-40	ROS: <1'/min FL: 2'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 1'/min FL: 4'	ROS: 255'/min FL: 16'	ROS: 346'/min FL: 20'
41-55	ROS: <1'/min FL: 3'	ROS: 1'/min FL: 3'	ROS: 1'/min FL: 4'	ROS: 1'/min FL: 5'	ROS: 255'/min FL: 17'	ROS: 346'/min FL: 21'
56-75	ROS: 1'/min FL: 4'	ROS: 1'/min FL: 5'	ROS: 1'/min FL: 5'	ROS: 2'/min FL: 6'	ROS: 282'/min FL: 18'	ROS: 372'/min FL: 21'
>75	ROS: 2'/min FL: 7'	ROS: 2'/min FL: 7'	ROS: 2'/min FL: 7'	ROS: 2'/min FL: 8'	ROS: 307'/min FL: 19'	ROS: 398'/min FL: 22'

Table 9: Fire behavior lookup table for mature broadleaf forest vegetation type

Vegetation: Broadleaf Forest (Mature)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: 1'/min FL: 1'	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 165'/min FL: 69'	ROS: 246'/min FL: 90'	ROS: 337'/min FL: 111'
1-25	ROS: 1'/min FL: 1'	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 166'/min FL: 69'	ROS: 248'/min FL: 90'	ROS: 338'/min FL: 111'
26-40	ROS: 2'/min FL: 2'	ROS: 3'/min FL: 2'	ROS: 103'/min FL: 50'	ROS: 174'/min FL: 71'	ROS: 255'/min FL: 92'	ROS: 346'/min FL: 112'
41-55	ROS: 4'/min FL: 2'	ROS: 5'/min FL: 3'	ROS: 114'/min FL: 54'	ROS: 184'/min FL: 74'	ROS: 266'/min FL: 94'	ROS: 356'/min FL: 115'
56-75	ROS: 7'/min FL: 3'	ROS: 8'/min FL: 3'	ROS: 130'/min FL: 58'	ROS: 200'/min FL: 78'	ROS: 282'/min FL: 98'	ROS: 372'/min FL: 118'
>75	ROS: 45'/min FL: 19'	ROS: 98'/min FL: 48'	ROS: 155'/min FL: 66'	ROS: 225'/min FL: 84'	ROS: 307'/min FL: 104'	ROS: 398'/min FL: 123'

Table 10: Fire behavior lookup table for mitigated broadleaf forest vegetation type

Vegetation: Broadleaf Forest (Mitigated)						
	Open Wind Speed (mph)					
Slope (%)	0	10	20	30	40	50
0	ROS: <1'/min FL: <1'	ROS: <1'/min FL: 1'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 246'/min FL: 16'	ROS: 337'/min FL: 20'
1-25	ROS: <1'/min FL: <1'	ROS: <1'/min FL: 1'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 248'/min FL: 16'	ROS: 338'/min FL: 20'
26-40	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 2'	ROS: 1'/min FL: 3'	ROS: 2'/min FL: 4'	ROS: 255'/min FL: 16'	ROS: 346'/min FL: 20'
41-55	ROS: 1'/min FL: 3'	ROS: 1'/min FL: 3'	ROS: 1'/min FL: 4'	ROS: 2'/min FL: 5'	ROS: 255'/min FL: 17'	ROS: 346'/min FL: 21'
56-75	ROS: 2'/min FL: 4'	ROS: 2'/min FL: 5'	ROS: 2'/min FL: 5'	ROS: 3'/min FL: 6'	ROS: 282'/min FL: 18'	ROS: 372'/min FL: 21'
>75	ROS: 3'/min FL: 6'	ROS: 3'/min FL: 7'	ROS: 3'/min FL: 7'	ROS: 4'/min FL: 8'	ROS: 307'/min FL: 19'	ROS: 398'/min FL: 22'

Appendix 4: Cal Poly Study Team

Single-Access Subdivisions Assessment Project:

Developing a Planning Tool for Evaluating Proposed Developments Accessible by Dead-End Roads

Prepared for

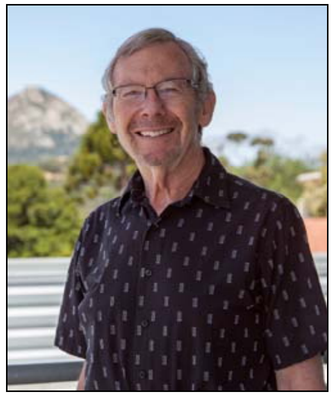
CAL FIRE and the California Board of Forestry and Fire Protection

By

California Polytechnic State University, San Luis Obispo

June 2016

This page intentionally left blank



W. David Conn, D.Phil., Principal Investigator

- Professor Emeritus, City & Regional Planning, Cal Poly
- Director, Cal Poly support team for preparation of 2013 and 2018 California State Multi-Hazard Mitigation Plans
- 44 years of experience at UCLA, Virginia Tech, and Cal Poly as a faculty member, administrator, and consultant

Cornelius Nuworsoo, Ph.D., AICP, Co-Principal Investigator

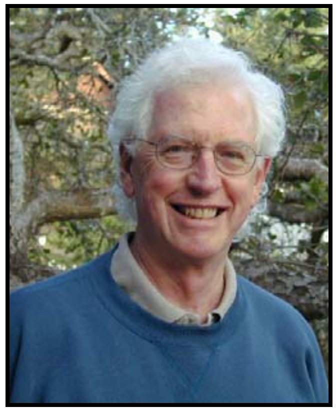
- Professor & Graduate Program Coordinator, City and Regional Planning, Cal Poly
- 14 years of field experience (transportation planning and traffic engineering)
- 10 years of teaching (transportation and land use planning)
- Developer of Access Model

Christopher A. Dicus, Ph.D., Co-Principal Investigator

- Interim Associate Dean, Research & Graduate Programs, College of Agriculture, Food & Environmental Sciences
- Coordinator: WUI Module of the California Fire Science Consortium
- Board of Directors: Association for Fire Ecology
- California Registered Professional Forester
- Certified Senior Fire Ecologist

Dan Turner, Senior Consultant

- Unit Chief (retired), San Luis Obispo Unit, CAL FIRE
- Executive Director, Urban Forest Ecosystem Institute, Natural Resources and Environmental Science Department, Cal Poly
- Manager, San Luis Obispo County Community Fire Safe Council
- Emergency Services Coordinator, County of San Luis Obispo, Office of Emergency Services



Kenneth C. Topping, FAICP, Senior Advisor

- Member and former Chair, San Luis Obispo County Planning Commission
- Senior Advisor, Cal Poly support team for preparation of 2013 and 2018 California State Multi-Hazard Mitigation Plans
- Director, Cal Poly support team for preparation of 2007 and 2010 California State Multi-Hazard Mitigation Plans
- Part-time Lecturer, City & Regional Planning, Cal Poly
- Former Visiting Professor, Research Center for Disaster Reduction Studies, Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan
- Former General Manager, Cambria Community Services District
- Former Planning Director, City of Los Angeles, 1986-1990